MANAGING SCIENTIFIC CHANGE IN AGRICULTURAL POLICIES: SOIL PRODUCTIVITY, RESOURCE CONSERVATION AND THE LEGITIMATION OF AGROBIOLOGY

by

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(ABSTRACT)

This thesis examines the conditions presiding over conceptual changes in soil sciences in Québec since 1960, and the legitimation of research in agrobiology. At the beginning of the seventies, researchers in soil sciences opted for a physico-chemical interpretation of soil fertility phenomena and for a scientific practice that involved analytical and experimental tools centered around the ionic movements of nutrients in soil solution and the attainment of high yields. Following soil degradation problems, researchers turned toward composting practices fostered by agrobiologists and foresters. After recognizing the role of organic matter in agricultural productivity, soil scientists adopted a biological interpretation of soil fertility and studied the role of microorganisms in the evolution of organic matter and in the provision of nutrients. The knowledge produced in soil biology benefited from the existence of a network of agrobiologists who, while insuring the diffusion of that

knowledge, secured the agrobiological identity of composting practices for soil conservation. The commensurability of experimental practices and theoretical entities in soil fertility and agrobiology, as well as the support of agrobiologists for applying the knowledge produced in soil biology legitimated research in agrobiology.

Acknowledgement

I would like to thank the professors who at one time or another have served on my committee -- Gary L. Downey, Richard Hirsh, Neil Flora, Bob Paterson, Richard Burian, John Luna and Peter Barker. Gary has been a very supportive chairman all through the years that were necessary to finally hand over a manuscript worth of this name. I also want to thank the people of the now defunct Science Council of Canada where this project originated, specially William Smith for having introduced me to the wonderful world of compost. Friends, relatives and colleagues have never stop encouraging me for a subject that sometimes draw their curiosity but mostly their irritability. From the first day when I applied to the graduate program in Science and Technology Studies to the last day when I defended my thesis, I have appreciated the patience and assistance of Carolyn Furrom and Peggy Stewart. My master's studies were made possible thanks to the financial assistance of the Natural Sciences and Engineering Research Council and the Social Sciences and Humanities Research Council.

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LIST OF ABBREVIATIONS

ABQ *Association de Biodynamie du Québec*
Association for Biodynamy

CECQ *Conseil des Engrais Chimiques du Québec*
Chemical Fertilizer Council of Québec

CPVQ *Conseil des Productions Végétals du Québec*
Crop Production Council of Québec

CRSAQ *Conseil de Recherche et de Services Agricoles*
Agricultural Research and Services Council of Québec

FABQ *Fédération pour l'Agriculture Biologique du Québec*
Biological Agriculture Federation of Québec

FPACES Federal-Provincial Agricultural Committe on Environemntal Sustainability

FSAA *Faculté des Sciences Agricoles et de l'Alimentation*
Agricultural and Food Sciences Faculty

GREPA *Groupe de Recherche en Economie et Politique Agricoles*
Research Group on Agricultural Economics and Policies

ITA *Institut de Technologies Agricoles*
Agricultural Technology Institute

MAB	*Mouvement pour l'Agriculture Biologique* Biological Agriculture Movement
MAC	*Ministère de l'Agriculture et de la Colonisation* Ministry of Agriculture and Colonization
MAQ	*Ministère de l'Agriculture du Québec* Ministry of Agriculture of Québec
MAPAQ	*Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec* Ministry of Agriculture, Fishery and Food of Québec
MENVIQ	*Ministère de l'Environnement du Québec* Ministry of Environment of Québec
OCIA	Organic Crop Improvement Association
SRS	*Service de Recherche en Sols* Soils Research Service
UPA	*Union des Producteurs Agricoles* Agricultural Producers Union

1.0 INTRODUCTION

1.1 Thesis statement

In this thesis, I examine changes in agricultural research in universities and governmental laboratories in Québec and analyze the conditions related to the elaboration and the legitimation of agrobiology, the body of knowledge of an alternative set of farming practices, biological agriculture.[1] I describe two bodies of knowledge in agricultural fertilization, respectively based on the use of synthetic chemical fertilizers and on composting. I present the bodies of knowledge and their related experimental, farming and social practices as networks of practices and

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[1] The French terminology used in Québec refers to *agriculture biologique* for describing the farming practices and to *produits biologiques* for identifying food commodities; producers indifferently described themselves as *agriculteurs biologiques* or *agrobiologistes*. The English terminology refers to *organic agriculture* for qualifying farming practices similar to the ones involved in biological agriculture; the term 'organic' is specifically used for marketing reasons, i.e. the labelling of food commodities as organic (see MacRae et al., 1989). Throughout the thesis, I use the following categories: 'agrobiology' and 'agrobiologists' for emphasizing the knowledge dimension, 'organic' for the market dimension, and 'biological' for both the market and knowledge dimensions.

expand the actual understanding of <u>legitimation</u> and <u>incommensurability</u> to actors' practices.

I raise this legitimation question since governmental and academic authorities in Québec have denied any scientific relevance or economical interest for agrobiology until recently.[2] Motivated by socio-economic and environmental factors, conventional farmers in Québec started adopting and developing agrobiological practices and knowledge by the end of the sixties. For twenty years, scientific and governmental authorities rejected agrobiology and refused to provide material and human resources for the development and diffusion of agrobiological practices. Today, academic and governmental scientists include agrobiology in their research agendas and public funds allow for the diffusion and adoption of agrobiological practices among the farming community.

I relate <u>incommensurability</u> to the unintelligible communication entertained between networks who articulate different soil fertility phenomena and implement fertilization practices reflecting their respective problematization. Agrobiology, based on ecology and microbiology, centers fertilization practices around the

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2 Castonguay (1990) presents an overall picture of the research infrastructure in agrobiology in Québec

provision of microorganisms for stimulating soil life and optimizing crop growing environment. Soil sciences, based on chemistry and physics, present soil fertility as the movement of chemical elements in the soil-plant complex and favour the application of chemical fertilizers for optimizing crop growth. Incommensurability impinges on the legitimation process as the dominant network does not possess a knowledge base for accommodating discourses and practices from the alternative network.

In this case study, I present legitimation as a two-fold process involving conceptual and institutional changes. Conceptual changes allowed the integration of alternative practices within the dominant network and rendered commensurable studies and practices in agrobiology and in conventional agriculture. Although these conceptual changes allowed the production of knowledge and practices on organic fertilization within academic and governmental laboratories, agrobiologists had to link these recent developments in soil sciences to their practices for legitimating their network. I then analyzed how, through institutional changes, agrobiologists maintained the identity of their practices and secured the legitimacy of their network.

To understand the legitimation of agrobiology, I will present the organization of the dominant network in governmental and academic laboratories and on agricultural fields, and of the alternative network on agricultural fields and in health food stores. Through the unfolding of three research agenda, soil test calibration, land application of manure and soil conservation, I will examine the changing experimental practices in soil sciences that allows a commensurability between the two networks. Finally, I will investigate the role of the community of agrobiologists in recovering the identity of their practices and legitimating their network. In the rest of this chapter, I will discuss other perspectives on the emergence of agrobiology and the theoretical relevance of my research to the field of science and technology studies.

1.2 Studies on the emergence of biological agriculture

Agriculture in the Western world underwent important changes after World War II with the widespread introduction of chemical products. The surplus of nitrogen in munitions factories following the end of the War favoured the introduction of nitrogen fertilizers in the American agricultural system (Tisdale et al., 1989). The emergence of scientific and technical expertise in extension services and agricultural colleges, set up by the Morrill Act of 1862 and the Hatch Act of 1878, allowed the diffusion of fertilizers and the development of practices related to their utilization; the model of agricultural scientific research set up in the United States largely influenced the one adopted in Québec (Gouvernement du Québec, 1979, *quoted in* MacRae et al. 1989).

Chemical fertilizers were among other capital intensive artefacts - pesticides, high yield varieties, heavy machinery and irrigation systems- that constituted the technical system of conventional agriculture. The introduction of these technologies entailed a large capitalization of farming activities. The importance of the costs involved and of the international trade of foodstuffs necessitated the expertise of agricultural economists. Regional concentration and specialization characterized the growth of the agricultural system in the second half of this century. Through its industrialization, agriculture obtained remarkable yields, sustained in part by scientific and technical advances. The production and distribution of technology, expertise and foodstuffs, at a local and international level, shaped an agricultural system, now referred to as conventional, characterized by dependence, centralization and specialization (Reveret et al., 1981).

These characteristics, not inherently detrimental if one considered the benefits of economies of scale for food production, were complemented in the sixties by another one, indeed more controversial: pollution. Different alternative movements contested the use of agrichemicals that created environmental and health hazards. Among those movements, the "back-to the-land" happened to be instrumental in the denial of conventional agriculture. People involved in this counter-movement and farmers experiencing technical and financial difficulties with the scaling up of their activities started practicing biological agriculture, a set of techniques developed by Albert Howard in India at the beginning of the twentieth century.[3]

Practitioners of biological agriculture faced severe criticisms from the agricultural establishment when they

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3 Petters (1988), who has studied the advocates of the American organic farming movement, found that a core of concerns about the "balance of nature", the revival of the rural fabric and the farmer's experience gathered practitioners and sympathizers motivated by diverse goals. Bussière (1986) has explored the motivations of pioneers in biological agriculture in Québec and related their activity to an "ideology of the rupture"; biological farmers wanted to demarcate themselves from the agribusiness by producing within an autonomous decentralized system and from the society of consumption by adopting a different way of life.

characterized their farming practices by their avoidance of chemical products. Proponents of conventional agriculture considered that this emphasis on negative criteria revealed that agrobiologists had nothing new to propose beside a return to ancestral methods (Forest, 1976). Further, agronomists claimed that agriculture, by involving living organisms, had always been biological (Aubert, 1972). Agrobiologists refined the specificity of their practices by relying on ecological concepts: nutrient cycling, population regulation, dynamic equilibrium and energy flows (Altieri, 1983). However, proponents of conventional agriculture considered that biological agriculture, by assuming a balance of nature, constituted a pseudo-science since ecosystems were in a constant state of disequilibrium (Forest, 1979).[4]

This type of opposition toward agrobiology lasted until the late seventies. Institutional support then started in the United States; the Department of Agriculture established an organic farming unit at its Beltsville

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4 Finding a unique definition that could satisfy the different actors was hardened by the different set of alternative agricultural practices that avoided synthetic chemical products: biodynamy, agroecology, organic agriculture, permaculture, low-input sustainable agriculture. Hill (1985) provides a thorough description of these practices.

Agricultural Research Center and published its Report and Recommendations on Organic Farming in 1980. The report provided a definition upon which actors involved in the debate could rely for ceasing their terminological disputes (Thériault, 1989).[5] In Québec, the Ministry of Agriculture resorted directly to that definition when it elaborated its Integrated Plan of Interventions in Biological Agriculture for providing resources to agrobiologists and insuring the development of biological agriculture (MAPAQ, 1987).

The provision of a consensual definition or the release of a governmental policy are manifestations, the products, of the growing legitimacy of agrobiology. One should not conclude from them that agrobiology is consequently legitimated. A more detailed analysis is required for understanding a legitimation process, i.e. the dynamic of an

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5 The USDA provided the following definition: "Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, green manures, off-farm wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds and other pests. (USDA, 1980: xii)"

alternative body of knowledge in removing different barriers inhibiting its recognition.

Busch et al. (1983) and MacRae et al. (1989) have examined basic assumptions in agricultural research that prevent fundamental changes from occurring. The authors mentioned reductionism, the scientific practice of dividing problems into manageable pieces for understanding single cause-effect relationships. According to MacRae et al. (1989), it prevents a holistic understanding of an agroecological phenomenon, "in which all factors, known and unknown, measurable or not, are constantly interacting (177)". For Busch et al. (1983), reductionism leads to the development of universal technologies that neglect the uniqueness of time and place of an agroecosystem. Finally, Busch et al. (1983) and MacRae et al. (1989) mention that, while researchers in conventional agriculture claim to perform a context-free and value detached science, practitioners in alternative agriculture acknowledge their acceptance of a socio-political framework and deny the objective ideal.

Students of the transition toward agrobiology have neglected examining the consequences on the knowledge content from introducing alternative farming practices; they consider transition as the substitution of one body of knowledge for another rather than as a process involving the gradual transformation of scientific practices.[6] This is best exemplified by Reveret et al. (1981) in their analysis of the emergence of ecological agriculture. From their interpretation of Kuhn (see 1.3), Reveret et al. (1981) have presented ecological agriculture as a new paradigm resolving the crisis faced by the scientific community incapable of internalizing anomalies encountered in conventional agriculture: water pollution, soil erosion, energy crisis. However, this represents a misunderstanding of Kuhn (1970) for whom the scientific community is internally regulated and cannot be affected by external factors.

Reveret et al. (1981) have limited their analysis of the knowledge content to the linear structure of conventional agriculture and the circular conception of ecological agriculture. These characteristics, as well as objectivity and reductionism, are among the demarcation strategies that scientists deploy for expanding their cognitive domain, monopolizing authority and resources, or protecting their autonomy (Gieryn, 1983). The debate over the definition of

6 Hill (1985) and MacRae et al. (1988, 1989) propose an evolutionary approach involving an efficiency/substitution/redesign progression in the transition to sustainable farming practices. This approach is concerned with changing farming practices but neglect the gradual transformation of experimental and scientific practices.

biological agriculture is filled with instances where researchers in agrobiology and in conventional agriculture resorted to rhetorical strategies for securing their research agenda.[7]

Students of science (Collins and Pinch, 1979; Gieryn, 1983) have analyzed legitimation as a demarcation dispute over the scientific character of one body of knowledge that threatens the cognitive authority in place. Treating discourse as an autonomous practice constitutes an insufficient description of authority or resources involved in a legitimation process; experimental practices impinge upon the production and the constitution of science and create barriers for the recognition of an alternative body of knowledge.

By neglecting the role of experimental practices, one might be inclined in considering scientific change as the result of a radical conversion. One must enlarge her understanding of science and add actions and materialities

7 Gieryn has related these strategies to boundary-work, the attribution of "selected characteristics to the institution of science (i.e. to its practitioners, methods, stock of knowledge, values and work organization) for purposes of constructing a social boundary that distinguishes some intellectual activities as "non-science" (Gieryn, 1983: 782).

to discursive practices for understanding how structural features impinge upon a legitimation process and for assessing the role of incommensurability in preventing scientific change from occurring. An examination of experimental practices allows one to symmetrically treat changes and continuities since, "it is action itself that serves as the mechanisms of mediation [between specific changes and specific continuities] (Downey, 1992: his emphasis)". Prior to studying the legitimation process of agrobiology, I will give an overview of recent treatment of scientific practices in science and technology studies.

1.3 Practices and incommensurability in 'Science and technology studies'

Part of the research in "Science and technology studies" aims at elucidating mechanisms of scientific and technological change. In his Structure of Scientific Revolutions, Kuhn (1970) presents scientists committed to a paradigm which provides them with legitimate problems and solutions for practicing normal science. However, scientists encounter anomalies, phenomena unexpected by the paradigm, that they either resolve or shelve. When an increasing number of shelved anomalies prevents the performance of normal science, the community enters a state of crisis, a phase of extraordinary science where emerging paradigms compete. One paradigm finally gains general acceptance among the community who continues its normal activity but with different standards, methods and theories.

According to one interpretation of Kuhn, scientists convert to a new paradigm without necessarily deciding in a rational way; distinctive world-views prevent scientists from communicating and rationally choosing between competing paradigms. This interpretation of scientific revolutions challenges many philosophers who conceive science as the chief example of rational thought. Denouncing the incommensurability thesis, other philosophers have attacked Kuhn for comparing scientific change to religious conversion (Shapere, 1962 and Lakatos and Musgrave, 1970). To replace mob psychology by rationality and scientific progress, some have articulated models of scientific change where a scientist rationally decides to pursue a different line of inquiry, in a research program (Lakatos, 1978) or in a research tradition (Laudan, 1977). Both approaches though face many shortcomings (Laudan et al., 1984).

Incommensurability draws its importance from considering science-as-theory. Hacking (1983) presents meaning-incommensurability in the following way.[8] Within a theoretical structure, a word gets a meaning through its links with others; when a theory changes, the meaning of a theoretical term changes, preventing comparison between competing or successive theories. For Hacking (1983), incommensurability constitutes a problem because meanings are conceived in accordance with our language use, instead of being seen as the result of an interaction with the world. Hacking (1992) later recalls that theories persist for their correspondence to phenomena scientists produced or even created and measured with instruments engineered in the laboratory. While theoretical accommodation of new results does not nullify the existing order of theory and instrumentation, the absence of links between phenomena of different instruments prevents a comparison between bodies of knowledge.[9]

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8 Hacking (1983) distinguishes three types of incommensurability. First, he considers topic-incommensurability as the difficulties in comparing succeeding theories that address different topics, concepts, problems and applications. Second, he presents cases where one tries to compare theories with completely forgotten styles of reasoning and system of categories. The third type is discusses in the text.

9 "It is just this literal incommensurability which also enables us to understand how a "closed system" can remain in use and also be superseded, perhaps in a revolutionary way, by a theory with a new range of phenomena. (Hacking, 1992: 31)"

Pickering (1986) also addresses the relationships between incommensurability and scientific practices. Local incommensurability stems from a fine grained analysis of experiments and refers to the culturally specific performative and interpretative practices of physicists who confirm the occurrence of a theory within its 'phenomenal domain'.[10] Global incommensurability reflects the different hardware used in experimental practices of two communities. Pickering notes that there may be an overlap between succeeding theories, but overall, questions about the partiality of incommensurability are simply, "striking implications of the social production [of scientific knowledge] (1986: 415, n11)".

The turn toward practices allows Hacking and Pickering to root the problem in the self-reinforcing nature of phenomena production, in terms of theory <u>and</u> experiment. However, such conception does not exhaust the problem of explaining the gradual passage from one theory to another, the abandonment of previous instrumentalities, and the inception of old conceptions in new explanations. Addressing problems of incommensurability and of transition between large-scale

10 Pickering (1986) adds that a choice between domains is irreducible as "it cannot be explained by the comparisons between predictions and data which were its consequence" (409).

paradigm, Barker (1989) suggests a model where practitioners (scientists) acquire competences in the proto-practices of a larger practice (paradigm). Succeeding practices share similar proto-practices that insure the historical continuity between practices. A scientific revolution results from the rapid replacement of a large number of proto-practices.[11] The time gap separating practices prevents them from competing.

Barker (1989) mentions that proto-practices may differ when combined with additional ones. The actor-network theorists makes a similar point about entities who have their significance and limitations defined by a network (Callon, 1986). With different networks defining an entity, the latter sees its identities constantly shifting; an actor can stabilize the identity of an entity by linking the interests of other actors to his problematization which include a role definition for each entity. Rather than debating about the role of non-human and human actors, a central feature of the actor-network theory, I will use the concept of network for

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11 Let me recall a criticism addressed to Kuhn for his model of scientific revolutions and the occurrence of a crisis in a scientific community. "If a few anomalies do not produce a crisis, but "many" do, how does the scientist determine the "crisis point?" (Laudan, 1977: 74). " Then how many proto-practices needed to be replaced?

understanding how a practice is defined in relation to other practices. The network of practices also refers to the community and institutions of practitioners.

Understanding a legitimation process between two incommensurable networks implies analyzing the inception of an alternative practice within the dominant network and the negotiations over the definition of that practice. This implies that a practice that overcomes incommensurability is not necessarily legitimate. Using tools and entities from agrobiology, soil scientists may interact with the material world in a context that denies the original function of the practice. To recover this function, agrobiologists must extend structural features of their network - agrobiological practices and institutions - to include a new context and secure the identity of their practice.

A legitimation process requires the existence of residual conflicts since it differs from a revolution where one network replaces another. These residual conflicts also demonstrate that the network is able to protect its core practices while it shares a number of practices and institutions within the dominant network. By analyzing how distinct practices are introduced in a different network and how they are combined for securing the growth of their original network, one might further provide a better understanding of a revolutionary process.

In the next chapter, I present the organization of two networks and the conflicts generated by the practices they put forward for achieving a self-sufficient agricultural production and for fertilizing crops. In chapter three, I examine how soil scientists modified their experimental practices to internalize problems facing conventional agriculture and how these changes rendered commensurable certain practices of both networks. In chapter four, I analyze how agrobiologists secured the legitimacy of their network despite their partial success in having agrobiology recognized as an environmentally sound alternative to conventional agriculture.

2.0 Two perspectives on a self-sufficient agriculture in Québec

During the sixties, the desire to build a modern and sovereign state brought a series of social and political changes to Québec (Linteau et al., 1989). The Ministry of Agriculture of Québec (MAQ)[12] envisioned attainment of food self-sufficiency for Québec by 1980. For the Research and Instruction Branch[13] of the MAQ, improvement of agricultural productivity necessitated a technical progress and intensive use of cultivated lands. Central to this strategy was a science that informed researchers about plant composition and growth (Forest, 1969).

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12 The case study covers the period from the late fifties to the early nineties. During that time, the name of the Ministry concerned with agricultural production changed four times: Ministère de l'Agriculture et de la Colonisation (1962-1972), Ministère de l'Agriculture (1973-1978), Ministère de l'Agriculture et de l'Alimentation (1979) and Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (1980-). I will use the acronym MAQ (Ministry of Agriculture of Québec) throughout the text for the sake of clarity, except for bibliographical purposes.

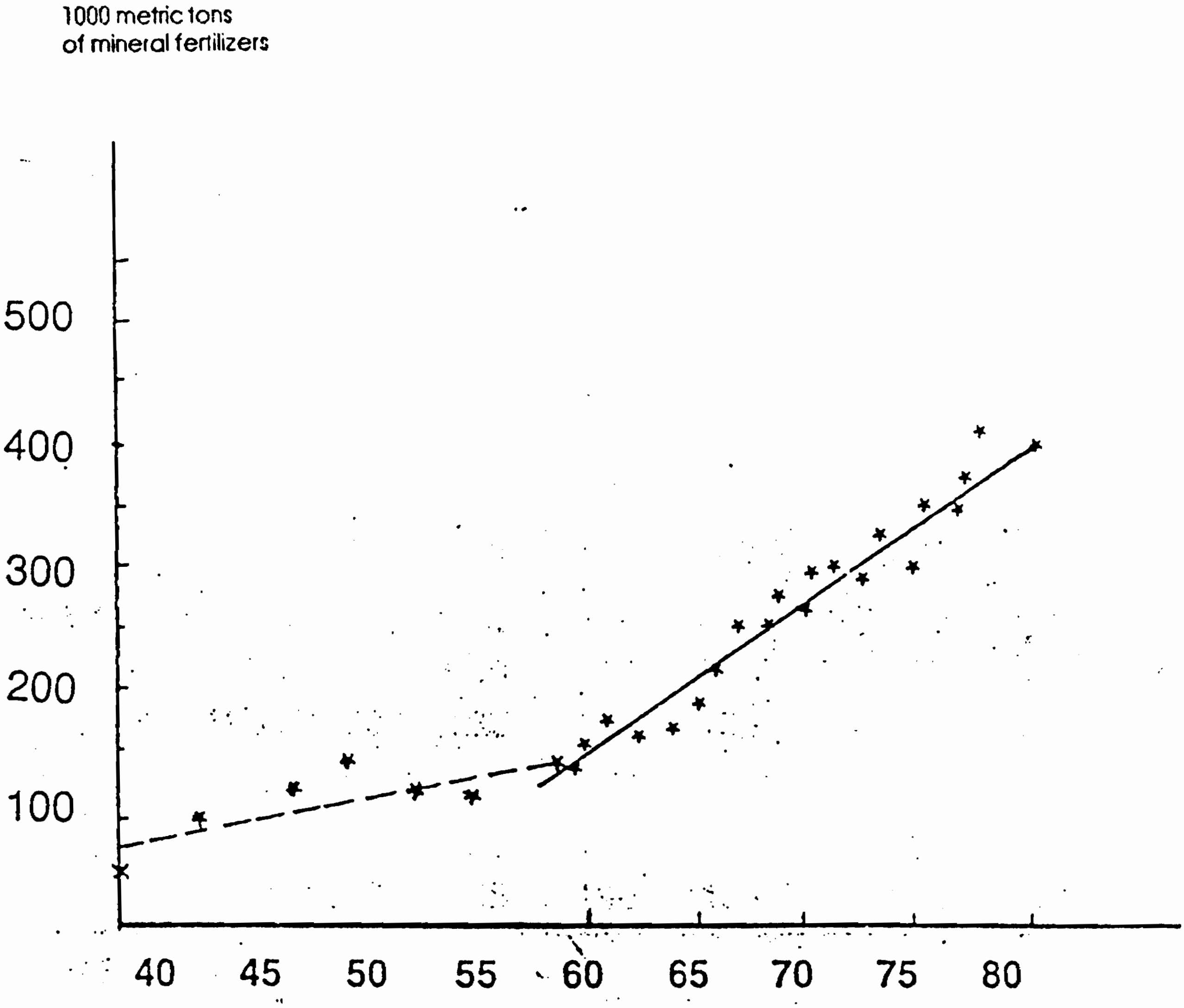
13 Three Branches elaborated and implemented policies for the MAQ: the Production, the Commercialization, and the Research and Instruction Branches.

A counter-cultural movement challenged this emerging 'agro-technocracy'. Adopting agrobiological practices from the United States and Europe, new rural dwellers, children of farmers and immigrants attacked the conventional system for its environmental impacts and for the model of development it generated (Thériault, 1989). Farmers, militants and health food cooperatives based the development of biological agriculture on regional autonomy, cooperative organizations for land accessibility and means of production, and local production of organic foodstuff (Reid, 1977). These different approaches on food self-sufficiency had implications for the institutional and conceptual dimensions of these two networks of agricultural practices.

2.1.0. The modernization of conventional agriculture: fertilizers and calibration trials

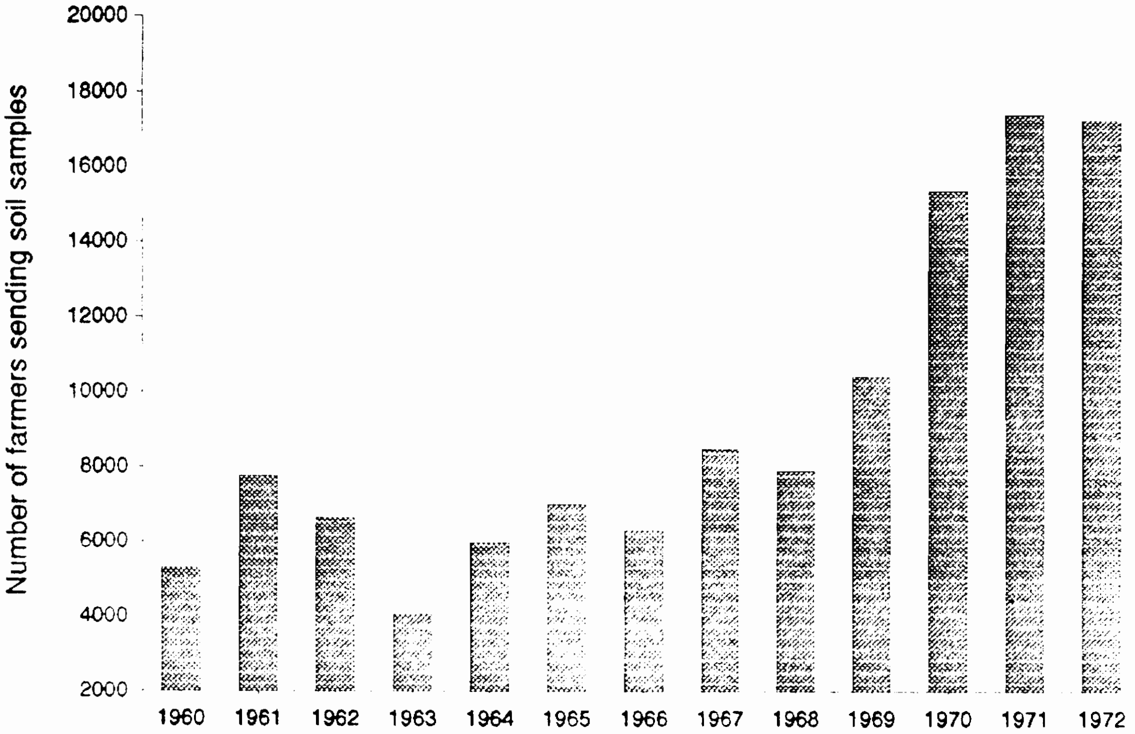
"The reason for the emphasis on higher yields in calibration trials is simple. Higher yields use more nutrients, the opportunity for response is greater, and results are more meaningful for the progressive grower. (Tisdale et al., 1985: 561)"

Governmental subsidies had extended the use of chemical fertilizers among farmers from 1960 to 1970 (Figure 1). When applying for fertilizer subsidies, farmers needed to present proof of an efficient use of fertilizers, by resorting to soil analysis, for example (Figure 2). Consequently, the MAQ



Source: Cescas (1982)

Figure (1)
Diffusion of chemical fertilizers 1940-1980



Source: MAC Annual Reports, 1960-1972

Figure (2)

Diffusion of soil analysis

had not only diffused a fertilization practice but also the resort to laboratory technicians for soil analysis (Figure 3). However, soil analysis and chemical fertilizers remained insufficient in improving satisfactorily agricultural production. At that time, average yields in Ontario and Canada surpassed the ones in Québec, despite the yields obtained by the best farmers or by researchers in their fertility trials (Forest, 1969). As researchers, agronomists and farmers required a common language for optimizing the use of chemical fertilizer, increased crop production awaited centralization of research and standardization of analytical practices.

Prior to its inclusion within the Research and Instruction Branch[14] in 1963, the Soils Division mainly supported two

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14 The Research and Instruction Branch also administered the Agricultural Research and Services Council (CRSAQ) and five Divisions. These were the Soils, the Crop Protection, the Apiculture and Acericulture, the Agricultural Research Stations and the Agricultural Technical Instruction Divisions. The Agricultural Technical Division included the Institutes of Agricultural Technology (ITA) in Saint-Hyacinthe and in La Pocatière that offered students with a professional degree. Such technical formation differed with the general instruction offered in colleges to students who wanted to later attend university classes. Agronomists graduated from universities, agricultural technologists from the ITAs.

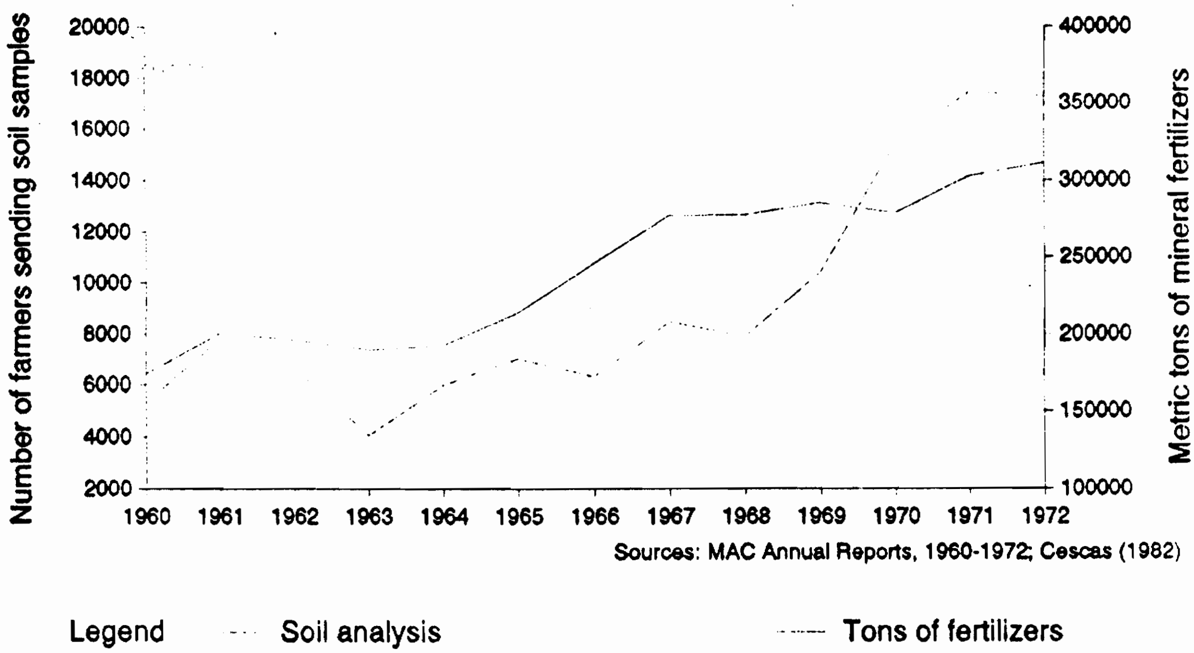

Figure (3)

Diffusion of soil analysis and chemical fertilizers mutual activities: soil classification and laboratory analysis. Pedologists presented the agricultural potential of different regions from a description of soil series based on physical and chemical properties provided by the Soil Laboratory of La Pocatière. With the closing of the Microbiological Laboratory[15] in 1964, biological studies in soil fertility solely concerned researchers from McGill University and from the Forestry and Geodesy Faculty of Laval University. In 1971, when a McGill researcher ended his studies on plant nitrogen nutrition from soil humic compounds, the Agricultural Researches and Services Council (CRSAQ) had financed its last biological research in soil fertility. A lack of resources within governmental research in soil fertility and recruitment of agronomists and engineers within the Division rendered unlikely any further development of a biological agenda in soil fertility.

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15 Researchers studying organic waste and bacteriological impacts of DDT required biological analysis such as soil respiration and nitrification test, humic acid analysis and microorganisms counts.

Fertility studies involved researchers from universities[16], federal research stations[17], and from the Soils Division gathered under the "Committee on Soils Fertility of the Province of Québec".[18] Researchers compared the impact on crop yield of three doses of each major nutrient and selected the optimal combination of fertilizers for obtaining maximum yields. This sharply contrasted with the traditional use of production function where the optimal combination of inputs was based on maximum profitability.[19] In fact, researchers assigned a secondary role to economic factors. MacKenzie

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16 The Macdonald College of McGill University in Sainte-Anne-de-Bellevue (west side of Montreal Island) and the Faculty of Agriculture of Laval University in Sainte-Foy (suburb of Québec City).

17 The three Research Stations of Agriculture Canada were located in Saint-Jean, Lennoxville and La Pocatière. A fourth one was established in Sainte-Foy in the sixties.

18 The Committee was responsible for studying soil types in relation to productivity and for collecting experimental data on soil fertility. Ouellette and Dionne (1965) who were members of that Committee, noted that soil fertility studies covered only fifteen of the 300 soil series identified by pedologists in 1962 and by 1968, they had conducted fifty-five fertility trials on cereals, forages and corn (*quoted in* Dubé (1986)).

19 A production function is an equation presenting the relationships between the variations of two sets of quantities, in this case of fertilizers and yields

considered inconclusive any economic assessment of yield increase since costs of inputs or prices of crops varied annually.[20] Choinière (1968) recalled that soil analysis was the only resort for farmers seeking maximum yields and minimum fertilizer cost. With a commercial balance of agricultural food commodities calculated in terms of yields, fertility trials addressed the MAQ ideal of a self-sufficient agriculture

From these experiments, the Québec Council for Chemical Fertilization elaborated fertilization grids (Figure 4).[21] Comparing the results of a soil analysis and data on a fertilization grids, an agronomists foresaw potential nutrient deficiencies according to the requirements of given crops; accordingly, he recommended a certain fertilizer dose for optimizing crop nutrition. However, these fertilization grids were mostly based on American data that did not

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20 MacKenzie (1979) compared fertilizer amounts for optimum economic returns and general recommendations of the CPVQ on wheat, corn, barley and soybeans crops. Using 1979 market prices, he found that only nitrogen recommendation providing economic returns for soybeans exceeded the CPVQ recommendations.

21 The crop uptakes the following amount of nutrients (N for nitrogen, P_2O_5 for phosphorus, K_2O for potassiuum), in pounds per acre, to reach the yields presented in column 2; this fertilization grid represents the basis of a fertilization program.(CECQ, 1968).

Récolte	*Rendement à l'acre*	*Prélèvement (voir note)* *N*	*P2O5*	*K2O*
Avoine	100 boisseaux de grain	65	25	20
	paille	35	15	100
	TOTAL :	100	40	120
Betteraves de table	10 tonnes de racines	66	8	80
	1300 lb de feuilles	86	10	54
	TOTAL :	152	18	134
Betteraves sucrières	25 tonnes de racines	124	49	216
	13 tonnes de feuilles	151	36	334
	TOTAL :	275	85	550
Blé d'automne	60 boisseaux de grain	75	35	15
	5400 lb de paille	50	15	95
	TOTAL :	125	50	110
Brome	3 tonnes	95	20	140
Carottes	20 tonnes	80	26	86
	1900 lb de feuilles	95	13	70
	TOTAL :	175	39	256
Céleri	30 tonnes de tiges	153	52	272
	racines	10	14	28
	TOTAL :	163	66	300
Choux	25 tonnes	225	30	210
Colza	35 boisseaux	70	105	105
Haricots de conserverie	250 boisseaux ou (8000 lb de haricots)	30	20	35
Haricots secs	40 boisseaux	127	40	73
Lin	15 boisseaux de grain 6450 lb de paille	69	46	91
Lotier	2 tonnes	95 (1)	20	55
Luzerne	6 tonnes	335 (1)	70	270
Luzerne (75%) graminées (25%)	6 tonnes	320 (1)	85	270
Maïs-grain	150 boisseaux	135	50	45
	6300 lb de tiges-feuilles	65	30	200
	TOTAL :	200	80	245
Maïs-ensilage	30 tonnes	200	80	245
Maïs sucré	6 tonnes	54	28	12
	3200 lb de feuilles-tiges	64	20	24
	TOTAL :	118	48	36
Mil	3 tonnes	82	30	110
Mil et trèfle	4.50 tonnes	185 (1)	60	175
Navets	10 tonnes	40	11	34
	2400 lb de feuilles	45	19	65
	TOTAL :	85	30	99
Oignons (terre organique)	20 tonnes	110	36	90
Orge	100 boisseaux de grain	110	40	35
	paille	40	15	115
	TOTAL :	150	55	150
Pois de conserverie	2 tonnes de pois	40	10	20
	6 tonnes de pesats	60	20	50
	TOTAL :	100	30	70

Source: CECQ (1968)

Figure (4)

Fertilization grids based on nutrient uptake necessarily reflect the growing conditions in Québec (CECQ, 1968). The formation of a consensus for improving fertilization grids occurred within the Crop Production Council (CPVQ), a consulting body set up in 1969 by the CRSAQ.

The CPVQ was in charge of conducting inventory on technical and scientific information available and applicable in Québec, and of developing agricultural research policy. From the requirements expressed by its different Sections and Commissions[22], the CPVQ recommended priorities to the CRSAQ who oriented, coordinated, and funded research within universities and Research Divisions. When, in 1970, the Soil Chemistry and Fertility Section of the CPVQ-Soil Commission replaced the Committee on Soils Fertility, researchers favoured speeding up the calibration program for establishing crop requirements and for verifying the actual fertilization grids (Dubé, 1986). By prioritizing the calibration of soil analysis, the CPVQ advocated the chemistry of soil fertility, from the experimental to the agricultural field, for obtaining the highest possible yields.

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22 It included members from the federal and provincial agricultural ministries, the academic and governmental scientific community, farmers' associations, and industries.

The multiplicity of analytical methods in calibration research caused coordination problems for the CPVQ-Soil Commission who elaborated a research policy on soil fertility (Cescas, 1971). Created in 1971, the Soil and Calibration Section encouraged methods that presented a singular relationship between a given nutrient and crop yields to quickly complete fertilization grids. Although agronomically sound for presenting nutrients interactions and establishing production functions, studies based on partial relationships required more time and space for factorial analysis and the CPVQ reserved them for long term studies and future correction of fertilization grids.

From then on, soil scientists classified soils according to their nutrient content[23], calibrated soil tests results against crop responses from applications of nutrients, and established fertilization grids for each crop (CPVQ, 1972). According to the nutrient content of the soil and the requirements of a crop, scientists elaborated a fertilization grid for recommending specific amount of fertilizer (Figure 5). Agronomists interpreted soil analysis and fertilization

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23 Following the Cate-Nelson (1971) method, a soil was classified poor, medium or rich according to its phosphorus or potassium content As for nitrogen requirements, relating N to crop response calibration trials and foliar diagnosis specified plant requirements.

grids for advising farmers about fertilization. According to the amounts of nutrients, the application modes, and the types of fertilizer that soil scientists used in their experiments, fertilization grids mediated fertility trials and agricultural production and framed a fertilization practice.

The CPVQ complemented the uniformization of experimental practices with the standardization of soil analysis in 1973 for a more efficient use of fertilization grids. With a spectrophotometer acquired in 1968 for simultaneous dosing of soil potassium, phosphorus, calcium and magnesium, the Soils Division set a standard for all of the laboratories offering farmers with soil analysis service.[24] The Methodology and Fertility Section of the CPVQ-Soil Commission provided laboratories with standard samples. Each laboratory performed samples analysis and related their results to those of the CPVQ (MAQ, 1973). Under the supervision of the CPVQ-Soil Commission, an inter-laboratory control continually insured concordance between results of laboratories and the ones of protocol.

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24 Ten local laboratories, from regional offices, the private industry, the Soils Division and Laval university, participated to the uniformization of analytical methods.

With the standardization of laboratory analysis and the diffusion of fertilization grids, the CPVQ built a network for extending the context of production of experimental results and reproducing them outside the laboratories. From its La Pocatière location, the Soils Division moved its offices and laboratories to Québec City in 1971. The Provincial Laboratory now strictly operated for researchers while the La Pocatière Laboratory continued providing farmers with fertilizer recommendations. Controlling at distance the efficient use of fertilizers, scientists pursued the completion of fertilization grids and introduced new experimental methods and tools for soil and plant tissue analysis.

Calibration of soil tests results against crop responses continued integrating the objective of maximum yields in fertilizer recommendations. Soil classification (see note 12) reflected the probability of crop response, in terms of percentage of maximum yields, according to the level of nutrients in the soil. For each crop, a calibration grid (Figure 5) presented the fertility level of a soil and, accordingly, the amount of fertilizer required to compensate the discrepancies between soil test values and amount of nutrients required by a plant for reaching its maximum dry matter content. While fertilization grids always required

Quantités de fertilisants en kilogrammes à l'hectare pour le maïs sucré (pH: 6.0 à 6.5)

Teneur du sol en phosphore	Teneur du sol en potassium: Pauvre -170 kg/ha			Moyen 171-280 kg/ha			Riche +281 kg/ha			Temps et mode d'épandage des engrais
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
Pauvre -85 kg/ha		80	80		65	55		65		Au labour.
	20	50	45	20	65	35	20	65	65	Au semis ou avant le semis.
	75			75			75			Avant 30 cm de hauteur.
	95	130	125	95	130	90	95	130	65	Total
Moyen 86-170 kg/ha		40	80		40	55		40		Au labour.
	20	60	45	20	60	35	20	60	65	Au semis ou avant le semis
	75			75			75			Avant 30 cm de hauteur
	95	100	125	95	100	90	95	100	65	Total
Riche +171 kg/ha			80			55				Au labour
	20	65	45	20	65	35	20	65	65	Au semis ou avant le semis
	75			75			75			Avant 30 cm de hauteur.
	95	65	125	95	65	90	95	65	65	Total

Quantité de fertilisants en kilogrammes à l'hectare pour le maïs-fourrage (pH:6.5)

TENEUR DU SOL EN PHOSPHORE	TENEUR DU SOL EN POTASSIUM: PAUVRE 0 à 122 kg/ha			MOYEN 123 à 234 kg/ha			RICHE · 235 kg/ha			EPANDAGE
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
PAUVRE 0 110 kg/ha	168	190	134	168	190	112	168	190	78	Enfouir avant le semis
MOYEN 111 à 206 kg/ha	168	112	134	168	112	112	168	112	78	Enfouir avant le semis
RICHE - 207 kg/ha	168	56	134	168	56	112	168	56	134	Enfouir avant le semis

(pour convertir en livres à l'acre, multiplier par .89)

Source : CPVQ (1979)

Figure (5)

Fertilization grids based on calibration trials

the application of a unique dose of nitrogen, different rates of phosphorus and potassium fertilizers were recommended. The reason for this was that soil analysis only addressed the less mobile nutrients, potassium and phosphorus.

Relationships between available soil nitrogen and crop response were unreliable; the mobility of nitrogen and its sensitivity to microbial factors rendered more difficult an assessment of the availability of this nutrient, considered as the pivot of fertility (CPVQ, 1978). Prior to launching the calibration agenda, researchers had already ceased assessing soil nitrogen content.(Ouellette: 1969 and MacKenzie: 1979) The abandonment of microbiological research in soil fertility further prevented any study of microorganisms immobilizing or releasing nitrogen. However, abuse of nitrogen fertilizers sometimes resulted in the lodging of cereals, in the poisoning of livestocks from pastured grass, or in the pollution of ground and surface water, besides increasing production costs. The importance of nitrogen in plants nutrition and the cost of nitrogen fertilizer required experimental methods for determining the fate of this nutrient, i.e. its leaching, volatization, fixation by clay or immobilization by microorganisms.

The CPVQ-Soil Commission considered that preventing excessive doses of nitrogen rested on plant tissue analysis. For more accurate fertilization recommendations, scientists determined a critical concentration at selected stages to calibrate plant tissue nitrates content against relative yields. Whether with the electrodes used by researchers from the Soils Division (Chamberland et Doiron, 1973)[25], with the atomic absorption procedures used by laboratory technicians (van Lierop, 1976)[26], or with isotopic dilution methods (van

25 Referring to existing links between plant growth and the ratio of a specific ion to the summation of ions found in soil solution, Chamberland (1972) introduced a method based on the principles of ionic activity in electrolytic solutions for determining the mechanisms of ions' transportation from soil solution to plant roots. The method consisted of an ionometre that measured the activity of a specific ion expressed by the potential difference of electrodes. Scientists correlated this potential with the tissue content of the specific ion and with crop yields for calibration grids.

26 In atomic absorption spectrophotometry, a cation, composed of an extracting solution and the nutrient extracted from the plant sample, is atomized into a flame where it receives a beam of light of a certain wavelength. The spectrophotometer measured the amount of energy from the wavelength that is absorbed by the atoms of the nutrient; this energy is proportional to the concentration of nutrients in soil solution. Different nutrients required different extractant solutions.

Lierop et Tran, 1983)[27], nitrate analysis partially embraced the soil-plant complex and hid the problem of nitrogen high mobility and dependency upon microbial activity. However, these instruments, and the theories underlying them, secured the centrality of chemical analysis for fertilizer recommendations.

Calibration studies not only framed agricultural production within the necessity of maximum output; it also reduced the language required to explain fertility phenomenon. For researchers in soil fertility and chemistry, the movement of ions from the soil to plant roots was principally accomplished by root interception, mass flow and diffusion (Tisdale et al., 1985). Mass flow consisted of the transportation of mobile ions from the water uptaken by the plant to replace water lost by transpiration; increasing the concentration of a nutrient in the soil solution enhanced the amount of that nutrient transported by mass flow to the roots

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[27] Researchers used a stable isotope, ^{15}N, to follow the evolution of nitrogen fertilizer. Distinguishing nitrogen fertilizer marked with ^{15}N from soil nitrogen (14N), Tran and van Lierop (1983) established the nitrogen balance of soil-plant system and the partial uptake of applied nitrogen from measurements of plant nitrate content. They related the supplementary uptake of soil nitrogen to the fertilizer impact on organic matter mineralization or on physiological factors like increased plant metabolism or root system absorption capacity.

for plant uptake. For less mobile nutrients like potassium and phosphorus, diffusion occurred with the movement of ions from an area of high concentration to one of low concentration, like the root surface constantly exhausted by plant uptake.

Through calibration trials and fertilization grids, researchers promoted the means and goals of agricultural production: the chemistry of the soil-plant relationships and the obtainment of maximum yields. These two assumptions not only defined the research activities but also promoted chemical fertilizers as the necessary agricultural practice. Farmers seeking eligibility for crop insurance or loans had to meet production standards set up by other agencies of the MAQ.[28] The policies of the Crop-Insurance Agency and the Agricultural Credit Office secured the assumptions underlying research in soil fertility and the resort to chemical fertilizers. Combined to other technical factors such as plant varieties and pest control, an increasing consumption of chemical fertilizers (Figure 1) allowed Québec to achieve a 58.2 % degree of self-sufficiency in 1979 (MAQ, 1979).

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28 For example, the Crop-Insurance Agency suggested farmers to sample plant tissue at growth stages determined by the CPVQ for late application of fertilizer.

2.2 The emergence and organization of agrobiology

While fertilization in conventional agriculture evolved around the utilization of chemical fertilizers, agrobiologists fostered the importance of soil microbial activity for producing food commodities; the basis of agrobiological fertilization was the provision of compost, a product resulting from organic matter degradation under aerobic conditions. The Research Branch, which had eliminated biology from its agenda by the late sixties, considered that the "ancestral methods" promoted by agrobiologists could only lead to the rise of food commodity prices (Forest, 1976). With the MAQ either marginalizing agrobiology or distancing itself from it[29], agrobiologists initiated different projects for adapting foreign techniques, training other farmers interested in agrobiology, and disseminating information. They also set up their own organizations for certifying and distributing organic products.

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29 For example, when in 1975, the Service of Research on Crop Protection established a network for phytosanitary warnings to diminish preventive insecticide treatments, the MAQ explicitly distinguished such project from a support to biological agriculture (Thériault, 1989).

2.2.1. The development and diffusion of agrobiological practices

When the Union of Agricultural Producers (UPA) requested financial assistance for experimenting biological agriculture, the MAQ supported agrobiologists in a remote area, the Gaspé Peninsula. The project aimed at compensating the lack of knowledge of farmers and of agronomists interested in agrobiology; it lasted from 1974 until 1979 under the guidance of the Service for Special Projects of the MAQ. An agricultural technologist, McInnes, participated with local farmers to collect data in the field about the alternative practices. He detailed the experiences in a 25 page brochure, acknowledging that it was more the result of bibliographical research than of a practical experience.

For McInnes (1976), actual agricultural research and instruction presented soil as a medium for physical and chemical factors affecting plant growth; agrobiology though favored soil life and microbiology and aimed at "feeding the soil to feed the plant". McInnes (1976) further distinguished fertilization practices in agrobiology by their role in optimizing on-farm maintenance and production of fertilizers, rather than simply providing substances to the soil. He concluded his document by claiming that the success of agrobiology depended upon the research devoted to it.

"In a sense, we are lucky that all the required researches exist. We only have to adapt it to our environment and verify it with farmers and researchers. If everybody performs and verifies their own research, we would write, and not summarize, an inventory of techniques in biological agriculture. (25)"

In the months following the publication of this report, Petit (1976) released his Compost: Theories and Practices, echoing the requirements for local research. Petit thought of popularizing composting in a French manual to overcome barriers toward a more rapid development of agrobiological practices, since most of the work in agrobiology was mainly published in English. In the absence of practical information for composting, this farmer had experimented diverse foreign methods with materials found on and around his farm.

Comparing composting practices and materials according to the piling procedures and nutrient content of the final product, Petit encouraged farmers in adapting techniques to their specific situation instead of adapting a situation to a technique. He also explored the use of compost, although modalities over its utilization as fertilizer remained to be determined:

"It is hard to determine the quantity of compost to use. It depends on crop type, previous fertilizer, soil fertility, compost quality, use of other fertilizers, rotation plan, etc.. (...) Only practical experience will allow one to appreciate the adequate quantity to use for satisfactory results (Petit, 1988: 12). "

Still, Petit provided a fertilization grid where he translated crop requirements in terms of compost decomposition degree: high, medium and fresh (Figure 6). For him, nutrients content insufficiently described compost value since it neglected the capacity to sow microorganisms in the soil and improve soil structure; agrobiologists needed then to optimize both the fertility and biological values of compost.

Petit often recalled the centrality of microorganisms in the soil and in the compost pile. He suggested producing and using compost during the spring or in the fall to benefit from an increase activity of microorganisms that fastened and eased the decomposition process of organic matter. For him, the importance of microorganisms in the heap was linked to the destruction of pathogens and weed seeds. He also mentioned that, in the soil, microbial activity and acids formed by the degradation of organic matter solubilized

Très décomposé	**Moyennement décomposé**	**Frais**
ail	asperge	artichaut
basilic	bette à carde	aubergine
carotte	betterave	cardon
céleri	(blé)	concombre
cerfeuil	chicorée	courge /
ciboulette	chou	courgette
échalotte	fraise	citrouille
endive	melon	maïs
épinard /	oseille	rhubarbe
tétragone	pissenlit	tomate
estragon	pomme de	
fenouil	terre	
fève	radis	
haricot / soya	raifort	
laitue	topinambour	
lentille		
mâche		
navet		
oignon		
panaïs		
persil		
poireau		
pois		
salsifis /		
scorsonère		
thym		

Source : Petit (1976)

Figure (6)
Fertilization grids for different composts

minerals and increased their availability for plant nutrition.

However, exploration of these mechanisms in soil sciences remained limited as researchers maintained nutrients within the mass flow movement and the diffusion process. They referred to the activities of soil microorganisms in explaining the nitrogen cycle but studied the later under its mineral form. Inorganic nitrogen compounds, like ammonium and nitrate, were converted in microbial tissue under an organic form, a process known as nitrogen immobilization. Conversely, the mineralization process involved the microbial decomposition of organic compounds of soil nitrogen, like amino acids and proteins, to release inorganic nitrogen for plant nutrition. With the dismissal of biological analysis and the absence of comprehensive testing methods of soil nitrogen, they relied on isotopic dilution and atomic absorption to understand crop nutrition of the mineral nitrogen they applied.

Proponents of the calibration agenda not only shortened the nitrogen cycle but also its studies. Temperature, moisture and other environmental factors influenced the activities of microorganisms in transforming soil nitrogen and organic matter. Uncertainties and time factors inherent to the study of microbial activities in releasing nitrogen contrasted with the desire of the Research Branch and of the CPVQ to rapidly diffuse calibration grids. As rapid progress in soil fertility knowledge required a limited number of factors affecting crop nutrition and a control of the entities under study, the Research Branch maintained aloof the study of biological fertilization.

Agrobiologists improved their composting practices by comparing the length of windrows, the amount of manure and the different material they composted, the weight of the final product, and the work it involved. Explanations were not central in the compost literature as major 'theoretical' issues consisted of boundaries drawn between methods.[30] The absence of devices (such as the paraphernalia of soil analysis and chemical fertilizers) embodying agrobiological knowledge required specific diffusion mechanisms; transfer of technical information depended on an organization grouping agrobiologists willing to exchange experiences, the *Mouvement pour l'Agriculture Biologique* (MAB-see 2.2.2). The latter

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30 Petit (1976) mentioned the following methods: Indore, quick return, fourteen days, biodanymic, anaerobic, scrub and surface composting (discussed in Chapter 3). For him, composting was a controlled process of organic matter degradation, surface composting had no agrobiological status.

offered a library service on agrobiological literature (it published and distributed Compost: Theories and Practices), and issued articles dealing with agrobiological practices in its newsletter; it also organized workshops during its annual congress and on-farm demonstrations during the growing season.

Despite these efforts, many agrobiologists experienced technical and financial difficulties and the MAB asked for governmental assistance to improve its technical expertise and its organization. The MAQ rejected the demands, claiming that its economic vocation overshadowed the minor economic importance of the MAB (*in* Perrier, 1984). According to Thériault (1989), the most important obstruction for recognizing agrobiology was from the Director of the Research Branch. For the latter, the scientific superiority of conventional agriculture allowed for the feeding of a growing world population while agrobiologists had no scientific grounds to demonstrate the negative environmental impacts of conventional agriculture or the nutritious superiority of organic products they claimed (Forest,1975; 1976).

Beyond these claims laid the orientations of agricultural research. On the one hand, the CRSAQ and the Soils Division had stopped investing in biological research on soil fertility and possessed no resources for assessing agricultural practices based on soil life and microbial activities. On the other hand, governmental guidelines strove for food self-sufficiency which were related to maximum yields (Forest, 1967; 1971; 1975). Agrobiologists adopted a small-scale bias and an idea of producing and consuming food commodities at a regional level; they opted for a diversification, rather than a regional specialization, in crop and animal production.

Following personnel changes at the head of the Research Branch, the Service of Special Projects formed a Joint Committee with the MAB in 1979 for planning the development of biological agriculture. A survey from the Service allowed the identification of biological farms; it also revealed that the market for organic food reached $CAN 20 million and that, despite the possibility to produce 60% of the products, the latter were mostly imported (MAPAQ, 1981). The Committee set up a project for establishing experimental farms in the twelve agricultural regions.

With the experimental farms, the MAQ wished to collect technical and economical data on agrobiology for popularizing agrobiological knowledge and for offering references to farmers interested in a more ecological agriculture (MAPAQ, 1982). Agronomists from the MAQ performed observations and kept track of data on farms managed by agrobiologists that the MAQ financially compensated; no experimental demonstration or workshop took place on these farms for other farmers. After three years, five participants had withdrawn from the project which, combined with the cost of the project, compelled the MAQ to cease financing the other agrobiologists involved (Ducas, 1988)[31]. In the meantime, the MAQ had identified greenhouses' production as a sector of potential economic importance to further develop.

Although many had hoped that such a project from the MAQ was a debut for supporting agrobiology, the technical references remained insufficient for farmers or agencies involved in agrobiology; the MAQ solely produced an evaluation report of the project. From its inception, the project on experimental farms had its orientation changed with the dissolution of the Service of Special Projects and of the Joint Committee in 1982; the technical requirements of the agrobiologists community remained peripheral to the economic interest of the MAQ. But when it ended its activities, the Committee had brought another issue to the

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31 For the MAB, the project failed due to the lack of communication from governmental officials; involved in the coordination of the project, the MAB had not been informed about the withdrawal of the participants and was not offered the possibility of replacing these participants (Perrier, 1984).

forefront: the commercialization of organic products through a system of certification.

2.2.2. Balancing the production and consumption of health food

Farmers, consumers and distributors of organic food set up two organizations for the promotion of biological agriculture in the early seventies. Producers in biological agriculture organized circles to exchange experience and information and overcome their isolation and initial economic marginality. Consumers and members of health food cooperatives also worked on organizing the distribution of organic products. In 1974, farmers, gardeners, sympathizers, and representatives of health food cooperatives established the *Mouvement pour l'Agriculture Biologique* (MAB), after having worked for a while in the *Mouvement pour l'Agriculture Organique* . By bringing together producers and consumers, the MAB wished to establish local exchange circles and to ease the regional planning for the production of food and the distribution of resources (Reid, 1977).

For members of the MAB, biological agriculture insured a higher nutrition value of food commodities, an improvement of soil fertility and vitality, and a reduction or an elimination of agricultural pollution. The political agenda of the MAB strived for regionalism and cooperativism. From its foundation, the MAB promoted biological agriculture through regional organizations and the establishment of a technical information service.

This group distanced itself from a newcomer in the realm of biological farming in Québec. The Organic Crop Improvement Association (OCIA) penetrated the Eastern Townships in Québec in 1973 and officially created a chapter in 1974. An American agency seeking to improve the quality of food and to regenerate rather than exploit natural resources, the OCIA was involved in all stages of the agri-food chain - production, processing and distribution (OCIA, 1987). With chapters in America and in Europe, it offered an advantage to producers seeking to market their products abroad, distributed and labeled by the OCIA. For the MAB, this implicit separation by the OCIA between production and consumption was unacceptable.

Both organizations benefited from the growing consumptions of health food during the seventies by consumers suspicious about conventional agricultural practices and food commodities. Health food stores and cooperatives organized four distribution centers in different regions to increase their purchasing power[32]. These centers acted as the core of the cooperative network until 1983; one of them became a warehouse of national scope in 1978. Although they enjoyed an annual growth of 30% in their first decade, only one of them and the national warehouse survived following the introduction of organic products in supermarkets (Fayat, 1984). According to Reveret et al. (1981), the network of commercialization the cooperatives organized helped to strengthen the development of biological agriculture in Québec.

For the promoters of organic products, the agrobiological conditions under which were grown such food commodities insured the protection of the environment and human health. This ecological dimension was complemented by a political and an economical one; the achievement of a relative food self-sufficiency by increasing the local supply of organic

32 Three categories of food need to be laid out here. Health food aims at improving physiological and psychological well-being of individuals (yeast, parsley). Natural products are foodstuff not chemically modified (concentrated juice if no citric acid is added). Organic products are grown under organic practices (use of green manure, compost, etc., where no chemical fertilizers, pesticides, antibiotics, growth hormones, etc. are used). These three kinds of products were offered in the cooperatives and health food stores, but appellations were often interchanged which allowed producers and vendors to fraudulently use such labels.

products (Fortin, 1985). While the development of biological agriculture in Québec was one of the main objectives of the cooperatives, 78% of the products sold in the cooperatives were from abroad. The weak organization of the MAB in its first decade rendered more difficult the adjustment between the needs of consumers and the capacity for agrobiologists to provide the demanded crops (Melançon and Martin, 1979).

The original idea of bringing together on a regional basis consumers and producers dissolved with the growth of the health food network and the consolidation of the national warehouse. Even if the price increase for products grown in Québec was lower than for products from abroad, cooperatives continued relying on foreign imports; important crops like wheat or legumes were not produced on a regular basis at a reasonable price (Fahndrich, 1984). Some agrobiologists benefited from a local market for specific products but many turned toward self-sufficiency on their own farm (Gélineau, 1977).

The absence of a central network for the distribution of perishable products was not the sole marketing problem for local agrobiologists. The absence of a clear definition about health, natural and organic products brought confusion among consumers. For promoters of biological agriculture, certification was a means to commercialize organic products and inform consumers about the practices involved in the production process. As mentioned by McRae:

"Those involved in promoting "organic" food were aware of what happened to the "natural" food market. Because "natural was not clearly described and protected, it was easy for the word to be coopted and used to describe any kind of food product or process." (1989: 51)

For the agrobiologists, certification represented a means to obtain a premium for their products and compensate the higher production costs related to a labour-intensive practice. The protection of this market niche represented a motivation for conventional farmers to adopt agrobiological practices despite the absence of government subsidies (MacRae, 1989). On the one hand, agrobiologists had no access to programs of loan approval from the Office of Agricultural Credit who denied their economic potentials. On the other hand, the Crop-Insurance Agency offered coverage on the basis of cropping practices generally recognized for a given production. When a farmer was not using conventional methods, he saw his indemnities reduced as the Agency related decreasing yields to mis-management.

The absence of governmental support to agrobiology hindered the production of data on agrobiological practices.

Conversely, the lack of data on agrobiological practices prevented agricultural agencies from recognizing agrobiology and elaborating a certification system. Agrobiologists mainly insured the diffusion and development of their farming and certification practices. This later impacted on the formulation of policy when the MAQ decided to support biological agriculture.

In 1980, the International Federation for Biological Agriculture Movements adopted its International Norms for the production and international trade of organic foodstuffs. The MAB published the norms in its newsletter of November 1982 and approved them for crop production and certification. The certification system was based on a control of production methods; farmers interested by the certification accepted to respect the norms and the control procedures. Inspectors financed by the MAB studied the background of farmers and visited farms to give the 'certification seal' used for commercialization of organic products. The MAB started to operate its certification system for crop production in 1985 and for animal production in 1989.[33]

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33 The Association of Biodynamy of Québec had its certification system, 'Demeter', in 1989. Following workshops given in Québec by a French biodynamist, Xavier Florin, some members of the MAB organized this association in 1979. Biodynamy involves the understanding of planetary

Producers, transformers and distributors of organic products were central to the OCIA's certification system. They conceived that all expenses related to inspection and certification was a valid investment for marketing their product, granted that the OCIA offered them an international network of consumers. Local chapters adopted a code of norms and a certification mechanism related to the federative rules of the OCIA. The regional basis of the chapters allowed producers to perform 'inter-evaluation'; inspections by third parties complemented the certification mechanism (OCIA, 1988). Producers kept a file on the inputs they used for inspection and legal representation. The OCIA chapter in the Eastern Townships started its certification program in 1983.

The MAB and the OCIA entertained little communication in their development because of the different philosophies underlying the orientation and management of their respective certification system. Protection of the consumer was central to the MAB's certification program; people interested in biological agriculture without being farmers themselves were involved in the certification system. It was the government's duty to protect the consumer against fraudulent producers or retailers and, more importantly, to provide them

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motions and other astral and vital forces in the production of crops. The ABQ is a member of the MAB.

with full information about the nutritious value of food and the production process involved. For members of the OCIA, certification was a marketing tool managed by the producers to develop domestic and exportation markets. Seeing certification as an investment, producers and transformers avoided governmental interventions that interfered with their own system. Besides, the OCIA seal protected a market niche for the members of the federation.

Biological farmers formed regional unions for establishing a marketing system for their products and operating the certification system of their chief organization. In the absence of a consensus between organizations in biological agriculture, the government could avoid the debate and assume its sole responsibility in that domain: insuring the protection of consumers' health. Besides, the MAQ had no intention in changing the actual system of food inspection and normalization (see 4.2.).

The lack of expertise in agrobiology prevented the MAQ from providing technical information to farmers interested in biological agriculture, and from certifying food commodities according to agricultural practices. The MAQ and agrobiologists resorted to a different knowledge production system with distinct fertilizing materials and experimental practices; their definition of food self-sufficiency also rested on a different scale. Unless common grounds permitted a recognition by the MAQ of agrobiologists, be that for their fertilizing practice or for their food certification systems, development in agrobiology would remain peripheral to any agricultural policies.

As demonstrated by the project on experimental farms and, to another extent, by the researchers of the Microbiological Laboratory, the provision of resources was an insufficient means for securing the development of an alternative agenda in agriculture. Agrobiologists and researchers in soil biology had to reproduce their knowledge outside their network, which required extending their original agenda or enrolling new actors. As soil scientists modified their experimental practices for answering different problems confronting conventional agriculture, agrobiologists saw their composting practices enlarged for including new concerns of the MAQ.

3.0 Changes in soil fertility studies: compost and composting as experimental tool and practice

From the early seventies on, the research program on calibration proceeded with researchers of the Soils Division and of Universities verifying and improving fertilization grids. The CPVQ popularized research through its technical bulletins and organized workshops for agronomists, technicians and farmers. A program insured the uniformization of soil and plant analysis through protocols and inter-laboratory controls under the CPVQ supervision. Experimental and farming practices promoted the use of chemical fertilizers while preventing an enlargement of criteria on soil fertility and agricultural productivity.

In 1976, the Service on Soil Research (previously the Soils Division) complemented its research facilities with an experimental farm for long term studies on calibration. In 1978, the Service undertook research on the residual and cumulative impacts of chemical fertilization under systems of monocropping and crop rotations. With an extension of the time-lenght of experiments, studies on nutrients residual impact extended the phenomenon under observation. Another series of experiments complemented chemical fertilization studies when, following growing discontent in the population and tougher regulations on manure disposal, the Service started working on the agricultural use of manure for preventing water pollution. With soil scientists remaining distant from a biological approach for understanding nitrogen behavior and manure transformations in the soil, the MAQ continued rejecting alternative farming practices.

3.1 The land application of manure: New problem, old agenda

The recent regional concentration and the specialization of farming activities, in livestocks or in cash crop production, had created severe manure management problems.[34] Farmers, who confined bovines in barns six months per year or raised swine and chicken in off-ground facilities, possessed insufficient space for land application of manure. As citizens formed coalitions to protect their rivers and engaged in lawsuits against farmers who discharged hog slurries in rivers, problems from manure mismanagement became

34 In the case of swine production, the number of swine raisers diminished from 17 000 in 1971 to 5 000 in 1978 while the production increased by 60% between 1973 and 1978; ten neighboring counties possessed 65% of the swine stocks in Québec.

irreversible.[35] In 1978, the Ministry of Environment (MENVIQ) held public hearings on a regulation project for the storage and land disposal of manure. The project required a farmer to have a capacity to store manure for 200 days and sufficient land to apply the manure generated on his farm (Government of Québec, 1981).

The MAQ, who had always discarded environmental problems from its jurisdiction, maintained its attitude within an Interministerial Committee created by the MENVIQ for regulating manure management. For the MAQ, treatment techniques such as recycling in animal food, biogas production and composting, only added a link to manure management, with a cost exceeding the actual value of the final product. Considering that the absorbing and filtrating capacity of the soil rendered land disposal the most efficient and less expensive way for manure treatment, the MAQ started promoting land application of manure while rejecting other alternative modes to manure management.

To determine the modalities of this farming practice, the Service on Soils Research initiated experiments where it used its calibration and soil analysis expertise to recommend

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35 The length of the thesis prevents a thorough analysis of the controversy over manure management.

quantities of manure to spread, according to the soil nutrition state and the crop requirements. Researchers compared average yields, soil samples and plant tissues for assessing the cumulative impacts of bovine manure applied every two years. Hog slurry though was a new element in the farming system and required specific strategies to address odor problems it created and uncertainties over its impact on crop yields. Trials involved the measurements of crop yields, soil organic matter content and extractable phosphorus and potassium for establishing the amount of slurry for land application. Researchers also observed soil physical properties disturbed by the slurry spreader and injector.

By their experiments, researchers reduced manure to different physical and chemical elements related to their understanding of soil fertility. They considered manure for its agronomic and commodity value and determined adequate doses for land application on the basis of soil analysis and fertilization grids (Figure 7). To meet crop requirements, chemical fertilizers complement manure application. Considerig that losses affecting nitrogen like denitrification, leaching, volatization and immobilization rendered unavailable half the nitrogen content of manure,

Culture	Besoin d'azote selon C.P.V.Q.	Dose de fumier frais*			
		Bovins	Porcs**	Pondeuses	Poulets à griller
	(kg/ha)	t/ha			
Maïs grain	170	67	57	16	15
Maïs fourrager	170	67	57	16	15
Blé	100	39	33	9,5	8,9
Orge	80	32	27	7,6	7,1
Avoine	45	18	15	4,2	4,0
Graminées	110	43	37	10	9,8

Source : CPVQ (1978)

Figure (7)

Recommended doses of manure (t/ha) for different crops

Dubé and Mercier (1980) established the utilization coefficient of manure to 50%.[36] The Service assumed continuity of the calibration agenda by transferring analytical tools, experimental design and studied processes; however, it ignored the biological characteristics of manure, considered like other fertilizing materials by its physico-chemical characteristics.

The MAQ wished that farmers would acquire a better knowledge of preventing water pollution from manure since "the rational use of manure [was] rather an exceptional phenomenon" (Dubé, 1980:3). It published a Manual for the Agricultural Use of Manure for local agronomists and farmers involved with manure management. The Manual dealt with sampling and analysis methods for determining the nutrient content and the monetary value of manure. As crop growers continued to rely on chemical fertilizers, land application remained a sanitary intervention rather than a fertilization practice. Variable qualities of slurry, odor problems and large volumes to

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36 The "utilization coefficient" compared assimilation capacities of nutrients released by organic fertilizers to obtain yields similar to the ones obtained by 100 Kg of mineral nitrogen.

handle[37] contributed to the reluctance of farmers in adopting this practice; animal raisers required alternatives for manure disposal.

Both storage and disposal practices met with resistance from the farming community who had suspicions from its previous experiences in manure management. Regulations so far had put forward practices that were not yet proven, as mentioned at the public hearings on manure management:

> "Farmers served and continue to serve as guinea pigs, experimenting at their own expense techniques not yet improved. Successively, there was concrete structures, not considered water-tight anymore, off-ground ditches that bursted, and plat-forms for solid manure that are not frost-proof (UPA, 1980: 15)."

The UPA rejected the proposed regulation because the important costs it involved for the farmers and for the lack of expertise in Québec on manure storage (UPA, 1980). For the UPA, it was the duty of the government to provide financial assistance to the farmers for preventing water

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37 The MENVIQ (1985) financed a series of research projects for the treatment of manure, the majority of them aiming at the separation of the liquid from the solid part of manure and diminishing the volume by 70%. This project was still under development in 1988 (Emond, 1988).

pollution, like the subsidies provided by the MENVIQ to the pulp and paper industry.[38]

Addressing the manure problem in terms of ditches and plat-forms construction contributed to the perception of manure as waste, confined to an expensive garbage-can (Boudier, 1983). The constraints that regulated the land application of manure harmed farmers' perceptions about the benefits of the practice (Gangbazo, 1985). For the MENVIQ, the environmental management of manure entered the agricultural world too slowly.[39] The delay was problematic for the MENVIQ who was then providing important subsidies to municipalities for the construction of water treatment facilities. As agricultural activities increased water pollution, it rendered inefficient municipal treatment facilities and forced municipalities to ban the use of their water.

38 The norms involved expenses of over $250 million for the farming community in building manure ditches or concrete plat-forms (Anon., 1979).

39 The MENVIQ found that, in 1986, 14% of the farmers met the requirements related to manure storage capacity and safety (MENVIQ, 1987).

3.2 The return of organic material on experimental fields

Black-boxing manure management was no easy thing. Besides the difficulties in operating efficient strategies for manure management, most discussions over the matter noted the partial character of any proposed solution. While the soil scientists and agricultural engineers of the MAQ concentrated their efforts on storage and land application of manure, agrobiologists and forest engineers promoted other 'partial' solutions for treating and using manure: heap and surface composting. Besides alleviating a pollution problem, composting in agrobiology and in forestry implied the conversion of natural resources to improve soil fertility and organic matter content. For the MAQ, who was also involved in some composting projects, these partial solutions had nothing to do with soil fertility and had to be kept away from the agricultural land.

The actors involved in organic material recycling based their composting practices on different knowledge bases and views about resource conservation. Disagreements about proper composting practices even occurred between agrobiologists. Farmers involved in the Gaspé experience considered that heap composting constituted a displacement of the manure pile, from the barn to the heap and, once composted, to the soil (McInnes, 1976). Unless they had to enhance the biological activity of an impoverished agricultural land or to fertilize small surfaces for intensive cropping, they preferred surface composting.

Surface composting consisted of leaving animal manure, green manure or crop residues decomposing on soil surface; farmers sometimes incorporated the organic material in the first inches of the soil. For McInnes (1976), it corresponded to the natural humification process occurring in forest or meadow. Humification on soil surface destroyed pathogens but not weed seeds. The destruction of weeds by physical means constituted a major problem for the farmers considering the short time for crop production in Québec. The work load though remained less important than for heap composting.

In his discussion of different composting methods, Petit (1976) had questioned the practice of surface composting which involved green manuring and soil incorporation of organic matter. Unlike a stable compost, large amounts of carbohydrate residues presented the risk of nitrogen immobilization and an uncertain fertilizing value for crop growth; it also monopolized large amounts of land. Although he recognized that surface composting required less work, he criticized the absence of control over the decomposition process. However, McInnes (1976) noted that surface composting met two principles in biological agriculture: permanent soil cover and humification of fresh organic matter prior to soil incorporation.

Surface composting maintained an ambiguous status in agrobiology, even more so when the practice reached the Service on Forestry Technique of the Energy and Resources Ministry (MER) who was exploring different means for converting forest residues. An agronomist of the MAQ, an assistant to the deputy minister and a forest engineer of the MER elaborated a series of projects in which they used forest residues as a source of organic matter to provide soils with a durable humus. They based their practice on the capacity of soil microorganisms for transforming organic matter into compounds for plant growth (Fortin et al., 1982). The researchers applied branched wood on tilled soil, later covered by manure and finally incorporated into the first five centimeters of the soil with an harrow; the addition of hog slurry prevented nitrogen immobilization.

After their first experiment in 1978, the researchers involved farmers for experimenting surface composting for cereals, potatoes and small fruit crops production. The farmers and researchers divided each field into three plots and used one as a control plot, another for yearly application of organic residues and the third one, composted in the first year, for assessing residual impacts of surface composting. They first attributed the increase in soil productivity to the provision of nutrients and oligo-elements from wood residues and hog slurry. After observing the changes to the soil structure and texture, they redirected their research toward other processes, linked to soil microbiology and pedogenetic processes, involved in the improvement of soil productivity.

Guay and Lapointe (1984) presented their adaptation of surface composting in the MAB newsletter. Petit (1984) later replied, questioning that their data had been obtained on a restrained experimental basis and with technicians not involved in agrobiology; validating surface composting in agrobiology required a comparative study with heap composting, using identical materials, soils and crops, in an experiment involving other agrobiological practices, like crop rotation. For Petit (1984), surface composting in agrobiology would require a larger amount of manure since nitrogen sources in agrobiology acted slower to prevent initial immobilization. Also, soil till before incorporation of composting material accelerated organic matter disappearance by oxidation.

Differences between the two practices involved more than the soluble minerals and the large quantities of organic matter used in surface composting.[40] Practitioners in surface composting wanted to provide the soil with organic matter while agrobiologists sought a stable humus and the presence of microorganisms. Both practices faced similar problems in their struggle for recognition by the MAQ. On the one hand, the Crop-Insurance Agency covered farmers only if they respected its directives and norms based on the use of agrichemical products, something neglected by both composting practices. On the other hand, the Service on Soils Research, aware of these recent development in surface composting, criticized the occasional absence of experimental design and of rigorous control over parameters (Dubé, 1983).

Research on organic material and chemical fertilizer differed from the directedness exercised in experimental

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40 In 1982, researchers from the Forestry Department of Laval University compared heap and surface composting for the optimal use of organic matter (Fortin et al., 1982). The authors did not draw any conclusion about the superiority of one of the processes. High temperature under aerobic conditions for heap composting destroyed pathogens and weed seeds but good aeration of the heap involved more work in terms of manipulation and organic matter transportation. Surface composting minimized nutrients losses, especially nitrogen volatization even if it sometimes caused nitrogen deficiencies in the soil and provided for an improved soil structure.

practices and from the use of statistical analysis. The decomposition of organic materials, incorporated or generated on site, contrasted with the application of soluble materials. Researchers in soil sciences and in forestry resorted to different mechanisms and analytical tools for explaining soil fertility mechanisms although they considered the same chemical elements; foresters based crop nutrition on biochemical rather than physico-chemical reactions and considered nutrients within organic compounds rather under their ionic form (Lemieux, 1986).

Considering the use of forest biomass as an organic amendment and its possible combination with hog slurry, the Service started conducting trials at the experimental farm in 1982 to remedy the controversial results so far produced. The Service integrated the trials on land application of hog slurry and forest biomass to its long term experiments on organic fertilization. Researchers performed different treatments with control plots and correlated measurements of chemical and physical parameters to identify the specific causes of any changes in soil fertility.[41]

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41 Trials consisted of eight treatments: a control plot, an application of slurry and six applications of wood chips, three of them complemented by three doses of hog slurry. Analysis in the first year

According to their respective goals, each research program used different materials for surface composting. The Service wished to replenish the soil organic matter content while providing another solution to manure management problems (Dubé, 1983). Foresters tried to increase yields by providing crops with physiological substances from organic matter degradation (Fortin et al., 1982). Unlike the wood chips used in the Service's experiments, the branched wood used by foresters possessed more carbohydrates, amino acids and proteins which, according to Lemieux (1986), played an important role in nutrient cycling.

For the Service, preliminary results on surface composting allowed the identification of certain beneficial effects on the use of this amendment. Forest biomass compensated for the low dry matter content of hog slurry, improving the possibility for increasing the soil organic matter content. Experiments involving the soil incorporation of organic materials were now part of the research agenda of the Service who directed future research on the decomposition process of organic material, with an analysis of organic matter evolution and of the soil microbial flora. For the MAQ, land

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concerned yields, soil organic matter and nutrients content, and, in the second year, residual impacts of organic materials application.

incorporation of hog slurry and forest biomass differed from composting, a term reserved for another agenda.

Considering the possibility to neutralize the polluting charge of hog slurry with small investment from farmers, the Service of Special Projects expressed some interests in compost production techniques by the end of the seventies. In 1980, a major swine raiser, Buteau, received technical assistance for producing compost on a large scale from an agronomist of the Service (Belzile, 1981). After one year, during which they experimented with different production processes with equipment, materials and labour actually found on the farm, they created "Composts du Québec Inc." for commercializing the product in bags or in bulk. They provided compost analysis and designed compost products for greenhouses and specific crop requirements. Buteau (1983) required more research on soil organic matter for enhancing the interests of nurserymen and gardeners in the use of compost.

Through its involvement in industrial composting, the MAQ maintained compost in activities peripheral to agricultural production. On the one hand, the absence of studies on crop fertilization from compost application perpetuated the use of compost outside the agricultural cycle. In its Manual for the Agricultural Utilization of Manure, the MAQ (MAPAQ, 1983) provided economic tables to price manure and apply it for crop fertilization but exempted the use of compost from an economic and an agronomic assessment.[42] On the other hand, farmers had to complement their composting practices with marketing strategies for selling their compost and competing against other amendment products.

The agenda around this composting practice aimed at alleviating pollution problems and fostering manure management practices in concordance with the MENVIQ regulation (Belzile, 1983). Neither industrial composting nor land application of manure helped to resolve the manure management crisis. Agronomists based the agricultural use of manure on the beneficial impacts of increasing soil organic matter content, such as soil structure improvement and microbial activity stimulation. As researchers neglected the articulation of these concepts within the experimental and theoretical apparatus of the agenda in soil sciences, organic matter remained peripheral not only to scientists but also to

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42 Based on the nutrient content of the manure, tables neglected important features of compost such as the role of oligo-elements and organic matter in soil productivity. The tables multiplied the amount of nutrients found in manure with the prices of similar doses of mineral fertilizers. Such calculations also overlooked the costs of water and air pollution from poor manure management, 'externalities' solely concerning the MENVIQ.

farmers.[43] Although soil scientists had integrated organic material in their research practices, organic matter reappeared in soil sciences after its depletion in agricultural fields.

3.3. Recovering organic matter through the economic assessment of land degradation

The manure crisis in Québec became part of the Canadian land degradation problem during the eighties. Different federal reports then described soil and water conservation problems and expressed them in monetary losses. The assessment of the economic impact of soil degradation in terms of reduced yields rendered irreversible a situation that remained within the boundaries of Agriculture Ministries. Federal and provincial governments elaborated on different strategies in soil conservation and paved the way for the enlargement of current soil fertility practices and for the introduction of composting and compost on experimental and agricultural fields.

The head of Soil Division during the sixties had previously asked for studies on organic matter properties and evolution

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43 Laboratories performing soil analysis measured the organic matter of the land; of the 69% of the farmers having their soil analyzed, 21% of them had its organic matter content measured (Boudier, 1983).

and policies for conserving or increasing this "precious element" of fertility (Scott, 1968). He had warned agronomists about chemical fertilization insufficiencies in improving soil productivity, a problem possibly alleviated by a combined application of chemical and organic fertilizer. At the same time, determination of soil organic matter content was absent from soil analysis in the first years of the Soil Test Calibration projects (1968-1973). During a span of fifteen years, soil sciences in Québec exclusively concentrated on fertility and pedology and neglected studies on organic matter.[44].

Most farmers in Québec had benefited from the original organic matter during the first years of cultivation by tilling their agricultural land on forest soil. With an emphasis on grain and silage corn production in Québec, many farmers converted typical rotations of a dairy farm to corn and cereal rotations, increasing row crops at the expense of hay and pasture crops. For Martel et al. (1980), these conversions modified organic matter quantity and quality and

44 While soil fertility studies allowed the CPVQ to publish calibration grids, pedological studies helped the provincial government to release a law for the protection of the agricultural territory in 1978; the law aimed at stopping speculation over arable land, as most of it was concentrated around urban area in Québec.

affected soil productivity. By requiring larger application of fertilizer, the ensuing decline in crop yields constituted an agronomic and economic problem.

Federal studies on soil degradation problems echoed this conclusion in the early eighties. With their respective policies on crop and animal production and markets, the provinces promoted certain cultivation practices and agricultural economies causing specific soil degradation problems.[45] The federal studies first covered the situation in the Prairies.[46] They nevertheless raised the issue at a national level and pointed to a common requirement; agricultural research and policies addressing soil conservation.

Coote et al. (1982) first presented different forms of land degradation and their related costs in a study that influenced many public and governmental organizations in

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45 Land degradation problems included wind and water erosion, organic matter depletion, weakened structure, compaction, salinization, draining activities, acidification and contamination.

46 Land degradation and financial difficulties had severely struck farmers in Alberta, Saskatchewan and Manitoba, who produced 55% of the Canadian agricultural output. Whether the financial crisis of that time rendered more acute economic problems of land degradation remained to be determined.

their understanding of problems related to soil degradation (Tabi, 1988). Another document that raised the problem to a national level was the report of the Standing Senate Committee on Agriculture, Fisheries and Forestry (1984). Public hearings across Canada on the land degradation situation enlarged concerns and mobilized interests throughout the country. While the latter document was the third one released by the federal government, it was the first one to address at length soil problems in Eastern Canada and Québec.[47]

A soil scientist from Macdonald College specifically reviewed land degradation problems in Québec for yet another federal study (Science Council of Canada, 1986). From an estimate of yield reductions and input increases, Mehuys (1984) presented numbers on the direct costs of compaction, water and wind erosion, and acidification.[48] For him, actual agronomic and economic data and the limited human and

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47 Also, Stress on Land (Environment Canada, 1983), and Challenge for Growth: An Agri-Food Strategy for Canada (Whelan, 1981) considered some forms of soil degradation in Eastern Canada, but not loss of organic matter, compaction, erosion or acidification, as most of the report concerned western Canadian agriculture.

48 Production costs involved lime application for remedying soil acidification and fertilizers, pesticides and seeds removed from transported sediments, run-off water and wind erosion.

material resources hampered rapid progress in identifying land degradation problems and in assessing the costs of other forms of land degradation.[49] On the one hand, increased use of fertilizers and improvement of crop varieties hindered the assessing of specific impacts of soil degradation on agricultural productivity. On the other hand, researchers were only concerned with measuring soil organic matter content, not with refining the relationships between organic matter depletion, soil structure deterioration and yield reductions (MacRae and Mehuys, 1984; 1987).

Mehuys (1984: 50) referred to past research policies in explaining the absence of information on soil degradation extent and cost to society:

> "Past research policies of Ministries of Agriculture have usually neglected the soil as an essential resource. Increased production at lower cost has always been the goal. (…) During the seventies, the Research Branch of Agriculture Canada, the largest purveyor of agricultural research in the country, embarked on a policy of management by objectives. The objectives were

49 A report on on-farm and off-farm costs based on crop yield reduction and other economic costs of land degradation also excluded organic matter depletion from an economic assessment (Agriculture Canada, 1986).

to increase productivity of crops which were listed as commodities. (...) This policy resulted in soil specialists being distributed thinly amongst the regional research stations to serve as support for other units in the plant or animal sciences."

Similar consequences affected research in Québec where the few soil scientists worked outside a specific agenda. Aware of the extent and the impact on agricultural productivity of the land degradation problem, the CPVQ organized in 1984 a workshop on soil conservation to quickly identify problems and solutions with agronomists, farmers and researchers from the MENVIQ, the MAQ and Agriculture Canada (Fournier, 1986). Following a request from the Assistant-Deputy Minister to the CPVQ-Soil Commission, most of these researchers collaborated in the production of a document summarizing their studies in soil conservation (CPVQ, 1986).

Although scientists agreed on the need for more research, the modalities of the latter remained to be determined. For some of them, a global and quantitative survey on soil erosion gravity was required to isolate sensible soils, identify the eroding ones, and elaborate intervention strategies (Dubé et al., 1984). Others asked for fundamental changes in the conduct of research, either by extending the time-length of experiments[50], or by involving different specialists in soil science (Côté et al., 1984). Besides adjustments in time and human resources, soil scientists needed to expand their actual theoretical apparatus and articulate other entities. Actual measurement of the C:N ratio remained insufficient for studying organic matter, the new pivot in soil fertility (CPVQ, 1986).

The researchers addressed the centrality of organic matter depletion, as a degradation phenomenon, and of organic matter management, as a conservation practice for stopping or preventing the different forms of soil degradation. Organic matter aggregated different soil particles, acted as a buffer against changing pH, and insured water retention. A complex and uncertain entity, it stimulated microorganisms that affected the nitrogen cycle; humic products from organic matter decomposition improved soil structure and stability against external aggressions.

Humus and microorganisms challenged the predominance of physical and chemical studies in soil sciences. These new

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50 "For soil specialists used to obtain quick response by adding fertilizers, the time length of experimental research necessary for the acquisition of positive results will be the most serious handicap to face if we want to improve and maintain soil structure." (Martel and de Kimpe, 1984)

theoretical and experimental entities in soil fertility allowed a revival of microbiology and biochemistry. The Service on Soils Research reoriented its quinquennial plan with the arrival of a soil biochemist and a soil microbiologist in 1983; it then undertook studies on organic material biodegradation and humification, and organic matter evolution in relation to soil microflora and microfauna (SRS, 1984). The Service relied on its experimental fields where it studied the residual impact of organic fertilization on crops yields to pursue its new agenda; these fields possessed replenishing organic matter and represented case studies for research on manure's transformation in the soil and impact on soil nitrogen and humus balance.

3.4. Humus, microorganisms and the biology of soil fertility

When research on organic material became important in the early eighties, scientists addressed the role of organic matter in soil fertility with the tools at hand: ionic activities, crop yields, and soil analysis of phosphorus and potassium content. Ionic activities in soil fertility had eliminated methods advocating entities other than soluble nutrients. The use of chemical fertilizers impacted in a similar way on the use of other fertilizing materials in experiments. Following soil degradation problems and the introduction of organic materials in fertility trials, researchers enlarged the pool of theoretical entities for specifying the role of organic matter in soil productivity and conservation.

Humus and microorganisms now assumed the link between the soil and the plant. In calibration trials, researchers applied a given concentration of nitrogen that circulated in the soil and was uptaken by the plant. In 'incorporation' trials, researchers applied organic material that microorganisms decomposed; nitrogen uptake followed microbial immobilization and mineralization. Measured once and for all in calibration trials, organic matter was a stable parameter characterizing the soil; bounded to its nature and its environment, it participated to plant nutrition through the digesting activities of soil microorganisms, themselves activated by the availability of carbon sources.

From their research on organic fertilizer residual impact and plant nitrogen uptake, soil scientists worked on the soil-plant-microfauna systems and forecasted nutrient availability. Researchers started basing soil fertility status on the humic balance, a method comparing humus losses and sources and pointing to soil organic matter requirements

(NDayegamiye, 1986).[51] Measuring humus content further required a qualitative assessment as the stability of the humic fraction regulated the intensity of the microbial activity in immobilizing nitrogen.[52] From 1985, the Service started describing the microbial population and humic characteristics of its experimental fields to indicate their fertility status.[53]

Determining the state of a substance contrasted with describing its modifications, organic matter being a dynamic process, the courtyard of microorganisms. NDayegamiye and Côté (1989) complemented their quantitative and qualitative studies of organic matter by characterizing the microbial activity and nitrogen mineralization potential of soils

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51 The CPVQ also echoed this shift from nutrients to humus analysis when it asked researchers to analyze manure dry matter content for determining manure humification potential; at the same time, it relegated nutrient content analysis to general information and macro-economic calculations (1986:91).

52 NDayegamiye and Dubé (1986) measured the stability degree of organic matter degradation products with a tool from humic chemistry, the 'optical ratio'. The spectrophotometric absorption of humic acids, measured at wavelengths of 465 nm and 665 nm, provided two measurements, E_4 and E_6; the 'optical ratio' corresponded to E_4/E_6. Related to the structures and links of humic substances, the ratio depended on molecular weight and condensation degree of humic acids and on the organic carbon content.

fertilized with bovine manure and hog slurry.[53] Linking the dynamism of microbial populations to the soil carbon content, researchers measured the quantity and activity of microorganisms in releasing nitrogen for crop growth. After overcoming risk of nitrogen immobilization by microorganisms, scientists now wished to prevent microbial oxidation of original organic matter; unbalanced content of carbon or nitrogen stimulated microorganisms that used nitrogen for protein metabolism and carbon for energy.

Studies of organic matter humification and microbiology constituted a renewal of practices in soil fertility studies, in terms of experimental material, analytical devices and fertility phenomenon. Referring to compost or pre-humified organic matter, and to surface composting or soil incorporation of organic material, researchers used similar parameters and analytical tools in their microbiological and chemical analysis: optical ratio, C:N ratio, microbial population, biological activity and nitrates evolution. From the mid-eighties, research projects at the Saint-Lambert

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53 Microbiological characteristics consisted of counting fungi, actinomycetes, bacteria, ammonifiers and nitrifiers. To determine soil mineralization potential and soil microbial activity, researchers resorted to recent versions of techniques used prior to the calibration agenda: nitrate test after soil incubation, and carbon dioxide trapping from soil respiration.

farm, at Agriculture Canada Research Station in Sainte-Foy and at Laval University addressed composting practices and the fertility of compost.

By verifying the impact of compost on soil quality and fertility, researchers used compost as an experimental tool and object. Between 1985 and 1987, NDayegamiye and Isfan (1991) worked on improving heap composting techniques using solid cattle manure with wood shavings, sawdust or peat moss. In each compost, they followed chemical and biological changes to measure the optimal duration time required to achieve a mature compost. They also performed fertility trials for determining the impact on yields and on nitrogen uptake of compost application. At Laval University, members from the Soil Science Department assessed the fertility of different composts for agrobiological greenhouses by measuring crop yields and the mineralization rate of organic nitrogen (Hébert et al., 1990).[54]

With the financial assistance of the CRSAQ and Agriculture Canada, other research projects on composting started at

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54 Financed by the Ministry of Higher Education and Science, the project was entitled "Value of humus as an organic amendment for greenhouse gardening" (FSAA, 1988).

Laval University.[55] In a three-year project on surface composting of diverse organic material under crop rotation, Laverdière (1989) measured the physico-chemical and biological properties of soils, crop yields and quality, and nitrate and organic matter evolution. In another study, researchers from Laval University and from the Service compared the effect of fresh and humified wood residues on yields and nitrogen immobilization to adjust nitrogen fertilizer recommendations (Beauchemin et al., 1992). The projects aimed at elaborating an operational model relating soil biological and chemical properties and crop yields.

After changing their fertilizing practices and enlarging their time-frame, scientists demarcated their experiments from the previous agenda by enlarging the phenomenon under observation and appealing to a different directedness. Nitrogen ions were in the soil and interacted with microorganisms and biochemical compounds, not pushed to the plant roots. Soil scientists relied on different parameters,

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55 At a time when the MAQ relegated compost outside the farming cycle, the CRSAQ financed Visser, a soil microbiologist and biochemist at Laval University, to characterize microorganisms in compost pile and study population change under pH variations (CRSAQ, 1982). The Natural Sciences and Engineering Research Council later financed Visser for studying humus impact on plant growth and on microbial activity and population growth (Visser, 1985 and 1986-a).

i.e. humic balance and nitrogen mineralization, to characterize soil productivity improvements even in the absence of yields increase. They also enlarged the range of practices deemed acceptable in fertility trials by using compost or by performing surface composting.

The involvement of new entities such as humus and microorganisms in soil sciences legitimated fertilization mechanisms other that the ones studied during the calibration agenda, a task not performed by the organic fertilizing material introduced during the manure management crisis. With researchers recognizing these other mechanisms, composting, as a soil and water conservation practice, and compost, as a fertilizing material, rendered commensurable studies and practices in chemical and organic fertilization. Compost provided the soil with humus and microorganisms, elements central in agrobiological fertility that were now necessitated for obtaining higher yields in conventional agriculture.

The legitimation of agrobiology involved more than the study, the use or the production of compost by researchers. Agrobiologists, who rejected chemical fertilization, related the agrobiological status of composting practices to the exclusive resort to biological mechanisms in explaining crop nutrition and in practicing crop fertilization. For them, scientists needed to integrate composting to other agrobiological practices and conducted on-farm collaborative research. They also wanted from the government a certification system to assure consumers that organic products resulted from a production process involving only agrobiological practices, hence a fertilization based on the sole use of organic material.

The study of microorganisms and humus represented a complementary aspect of their scientific practice still based on a physico-chemical interpretation of fertility phenomena. Soil scientists used analytical devices in soil biology for further defining a farming practice that would alleviate the declining productivity of agricultural land. Assessing the humification degree of organic matter and the biological activity of the soil complemented rather than replaced existing analytical tools in soil fertility. Based on the practices of agrobiologists and foresters, compost was combined to chemical fertilizers in fertility trials; changes in experimental practices now integrated components of agrobiology.

By involving common experimental practices, soil biology rendered partially commensurable the two networks of practices and provided a knowledge base for assessing and funding projects involving the use of compost. Biologists, biochemists, and microbiologists in forestry and agriculture insured the reproduction of the knowledge base by forming a Section on biology and fertility within the CPVQ-Soil Commission (CPVQ, 1989-a). With soil scientists considering composting mainly as a soil conservation practice, the legitimacy of agrobiology relied on the adoption of composting outside the realm of scientists. After having supplied soil fertility studies with their practices, agrobiologists insured the diffusion of the knowledge produced in soil biology. Their network of practitioners diffused composting as a soil conservation and fertilization practice.

4.0 The legitimation of knowledge and institutions in agrobiology

Soil microbiologists and biochemists in governmental and academic research facilities re-introduced analytical devices for studying neglected participants of soil fertility phenomena, humus and microorganisms. Knowledge produced in soil biology required further dissemination; otherwise it would remained confined to soil scientists and laboratory technicians like in the early sixties. Agrobiologists now provided a social space for diffusing knowledge in soil biology. With financial support from federal and provincial governments concerned by land degradation problems, they pursued their agenda by integrating composting to other agrobiological practices and centering fertilization around the stimulation of soil life.

The commensurability of experimental practices was an essential but insufficient condition for the legitimation of agrobiology, a process involving other agricultural policies than research: instruction, extension services and commercialization. The MAQ recognized these other aspects of agrobiology by releasing the Plan for Integrated Interventions in Biological Agriculture in 1989. Just as past governmental involvements maintained agrobiology in periphery of the overall agricultural system, either in the Gaspé peninsula or in the experimental farm network, the Plan risked producing a similar impact. Agrobiologists though possessed the means to secure the growth of their network while preserving a core of practices.

4.1. Knowledge diffusion in soil conservation

Between 1987 and 1989, Agriculture Canada and the MAQ concluded three agreements for soil and water conservation.[56] Aside from displacing existing money and projects under new labels, the Agreements provided new resources for developing and diffusing composting practices.[57] The major project stemming from the Agreement on Agri-Food Development was an inventory of land degradation problems by the MAQ. The method for the inventory consisted of relating soil properties to stresses resulting from cropping modes and

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56 The Canada-Québec Auxiliary Agreement on Agri-Food Development 1987-1990, the Canada-Québec Auxiliary Agreement on Agricultural Soil Conservation 1988-1992 and the Canada-Québec Auxiliary Agreement on Regional Economic Development, 1989-1993

57 For example, researchers from the Service on Soils Research and the Soils Science Department of Laval University originally received grants from the CRSAQ for experimenting surface composting; following the ratification of the Agreements, joint funds now allocate money for these research projects.

practices specific to plants (Tardif, 1988). From a cartography of 400 soil series in Québec, the Pedology Division of the Service on Soils Research designated soils for an analysis of their mechanical and chemical properties (Tardif et Tabi, 1989).

The Service, which had started reconsidering soil biology in addressing problems of soil degradation, maintained a physico-chemical language in its Inventory. Actual human and material resources prevented describing the soil biological characteristics on a provincial scale. Researchers involved in soil biology were too few and methods for assessing the biomass and the microbial activity of the soil were time-consuming and tedious (Bourguignon, 1989). Moreover, regional laboratories had not yet introduced biological analysis in their routine diagnosis and the resort to a central laboratory would have further complicated the activities of researchers working on the Inventory. The scarce resources in soil biology also impacted upon the diffusion process of composting practices.

Experimental changes addressing land degradation problems needed to be transferred to farmers but governments lacked the necessary expertise. Although researchers studied composting processes and practices, the agronomists of the MAQ had not acquired any training in that domain, hindering the diffusion of soil conservation practices. The absence of a knowledge base had already prevented the MAQ from enabling agrobiologists to initiate composting projects in the early eighties; the MAQ then based its refusal on its lack of expertise for assessing the projects submitted by the agrobiologists (Lachance, 1982). The involvement of the MAQ in industrial composting, although beneficial for preventing water pollution, had a limited impact for developing expertise in soil conservation.

While the Service (1981, 1982) and Mehuys (1984) had expressed the need to follow development in agrobiology for crop fertilization and soil labour, the MAQ maintained a certain distance toward the use of compost as a fertilizing material. By simultaneously rejecting agrobiology and composting practices, the MAQ prevented the formation of professionals for offering extension services on these subjects. When they recognized composting as a soil conservation practice and the necessity to resort to such practice, the governments supported farmers and organizations introducing, developing or adapting composting practices for soil conservation.[58] The MAQ then relied on agrobiologists

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58 The program "Technological innovation in soil and water conservation" financed farmers experimenting surface composting with crop rotation, comparing soil humic balance and fertility following

who had developed the necessary expertise and experience in diffusing composting knowledge.

After organizing workshops and on-farm demonstration during the seventies, agrobiologists received financial assistance from different ministries during the eighties to provide a training on agrobiology in governmental institutions.[59] The MAQ maintained its regular instruction program, besides offering an introductory course on agrobiology at the ITA in La Pocatière since 1983. From 1982, agrobiologists started teaching part-time courses in composite schools under the guidance of the Education Ministry. In 1985, the Vocational Training Board of the federal government financed a full-time program entitled "Self-managed ecological farming" at the secondary level. Two agronomists of the Institute and fifteen agrobiologists introduced the program at the ITA in La Pocatière the following year. In 1987, the Ministry of Higher Education and Science allowed the CEGEP in Victoriaville to offer the first degree in agrobiology in a program set up by Petit and the MAB (Daigle, 1989).

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application of different composts, and introducing machinery for heap turn-over and aeration (Agriculture Canada, 1991).

59 The clerical and legal services of the MAB were paid by the Ministry of Leisure, Hunting and Fishing (Bussière, 1986)

Knowledge transfer in agrobiology was not a matter of diffusing an artefact but providing new dimensions to actual agricultural practices. On the one hand, agrobiologists, with demonstrations in the field and farm visits, presented composting combined with other agrobiological practices in animal husbandry, crop rotation, pest control, and soil conservation (Thériault, 1989). On the other hand, composting accomplished three goals in agrobiology. It was a means for on-farm recycling of resources like manure and crop residues, for improving soil structure, and for providing the soil with microorganisms which rendered nutrients available to plant consumption. The first two goals answered problems confronting conventional agriculture but the third one challenged conventional fertilization practices with microorganisms competing against chemical fertilizers.

The MAQ rather considered composting as a practice that farmers better acquired for soil and water conservation. After relegating compost outside the farming cycle, the MAQ now sought an integration of compost and composting into farmers' practices. The MAQ and the MENVIQ combined the budget of their respective program on manure management to finance a feasibility study for implementing composting units and practices on dairy farms (ACSI-BIOREX, 1989). In 1990, it further allocated funds for the development of a computer software for assisting farmers in the optimal use of organic fertilizers produced on the farm. It also financed researchers at Macdonald College for developing farming infrastructures for simultaneously storing and composting manure.

Integrating manure management and composting in a building or on a software was one step too far for agrobiologists; they considered that, by black-boxing farming practices, these strategies accepted the actual development of agriculture. Adding compost to monocropping and chemical fertilization practices hid the disruptive environmental impacts that agrobiologists blamed conventional agriculture for. Moreover, compost would lose its identity as an agrobiological practice which would impede upon the recognition of the whole network. The legitimation of agrobiology was not simply a matter of adopting farming practices independent of each other. When converting to agrobiology, a farmer had to adapt agrobiological practices to his farm through experimentation, starting with an improvement of organic matter management; central to that process was an assessment of the resources on the farm, considered as a whole (Gélineau, 1990).

The MAQ and Agriculture Canada financed eight regional farmers' associations who organized demonstrations on heap composting and planned the transition toward biological agriculture. Among those associations, a local chapter of the UPA in the Lanaudière area experimented the transition toward biological agriculture with the assistance of members from the Ecological Agriculture Projects.[60] An extension agent from McGill University underlined the importance of that project "since it involved the revision of the overall management of the dairy farm for preserving the farm's resources, in a physical and biological sense (Fournier et al., 1990; 76, *my emphasis*)". Another important aspect of projects dealing with transition toward biological agriculture was the involvement of regional groups. For agrobiologists, it enhanced the exchange of information and experiences between farmers and compensated for the lack of applied research and technical improvement in regions (Gélineau, 1990).

After recognizing practices proper to agrobiology, for composting and knowledge transfer, the MAQ now resorted to agrobiologists for providing technical data on composting

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60 The Ecological Agriculture Projects consisted of an information center on alternative technologies and agrobiology. It was launched in 1974 by faculty members of the Macdonald College who then deemed limited access to useful information to be an impediment to the development of agrobiology.

practices. The Center for the Development of Agrobiology in Québec (CDAQ), established in 1989 by Petit and two other agrobiologists involved since the seventies in instruction and production, received grants for assessing the agronomical, technical and economical aspects of two heap composting scenarios with different turn-over systems and animal manure. The CDAQ deemed participation of farmers as essential to the development of agrobiology and, in that respect, two dairy farmers participated in the research project.

The acceptance of agrobiological experimental practices by scientific authorities was not unidirectional as recent development in soil sciences permeated the activities of agrobiologists. The CDAQ set up a laboratory for providing its members with soil, compost and humus analysis and it organized experimental plots for measuring the impact of different composts on crop yields. Rather than seeking universal replicability of their research findings, agrobiologists recognized that each farm had its own set of good solutions; it was up to the farmers to perform on-farm research and adjust future application of compost from personal judgment based on "whatever means they are comfortable with (a good eye, weighing or tissue analysis)" (Patriquin, 1988). Agrobiologists avoided compromising their approach to agriculture when resorting to analytical means developed in agricultural sciences.

Opportunities for combining agrobiology and agricultural science increased with the beginning of a curriculum on agrobiology at the two universities in the late eighties.[61] After overcoming departmental boundaries, researchers from both universities proposed a multi-dimensional approach in agricultural production for studying farm-scale agronomic and economic conversion to biological agriculture.[62] At Laval University, researchers studied composting as an activity for soil conservation and fertilization and integrated it with other agrobiological practices; this project led two graduate students, Hébert and Robitaille, to publish departmental publications on agrobiological fertilization based on the use of compost.[63] The CDAQ later edited these works and diffused them among the agrobiological community.

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61 Laval University started offering a major in bio-agronomy in 1988 and McGill University, a minor in ecological agriculture in 1990.

62 While Laval University acquired a dairy farm to experiment the transition, researchers from McGill University monitored the farmers from the Lanaudière area (see above) (Thériault et al., 1990; MacRae et al., 1988).

63 The work concerned compost heap management and dimension, crop and soil fertility evaluation and grids, fertilizing value of different

By considering the farm as a whole and acknowledging its specificities, and by avoiding a piecemeal approach where practices would be considered separately and introduced as "magic bullets" for remedying specific problems of conventional agriculture, researchers followed agrobiologists' practices and principles. The MAQ pursued this trend when it oriented the experimental farm of the ITA in La Pocatière toward the development and transfer of agrobiological practices and established there the Biological Agriculture Center for developing its own expertise in agrobiology.[64] This intervention of the MAQ was part of the Integrated Plan of Interventions in Biological Agriculture (MAPAQ, 1989), a policy that addressed both production and consumption dimensions of agrobiology and relied on the infrastructure set up by agrobiologists for diffusing knowledge on agrobiological practices and for distributing organic products.

The network constructed by the agrobiologists for the last twenty years was now the stepping stone of governmental

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composts, and the impact of fresh and composted manure on soil physical properties (Hébert 1989 a-b, Hébert et al.1990; Robitaille, 1988, 1989 a-b).

64 The ITA also integrated classes previously taught in the continuous education program to the curriculum of regular students.

interventions in providing technical assistance to farmers in agrobiology. For ensuring an adequate supply of information, research findings and technical advice, the MAQ linked the documentation center of the Ecological Agriculture Projects to its twelve regional extension offices. Each regional bureau possessed an extension agent with technical expertise in agrobiology that the ITA or the CDAQ had trained; these institutions also received funds for organizing on-farm demonstrations for farmers and agronomists. Finally, the MAQ allocated funds to its Research Branch for agrobiological research according to priorities set up by agrobiologists and scientists gathered under the Committee on Biological Agriculture of the CPVQ.

Despite their acceptance of agrobiological entities and practices, governmental researchers protected the legitimacy of their practices by denying the role played by agrobiology in providing an environmentally sound alternative to conventional agriculture.[65] Unlike the universities who

65 Within the structure of the CPVQ, a Committee corresponded to a specific market sector, like maple syrup or honey or grain, while a Commission addressed research domain like soil, engineering, weed control, agrometeorology. The CPVQ based its involvement in agrobiology on the fact that the latter "corresponded to a need expressed by consumers since the demand for organic products ceaselessly increased" (CPVQ, 1989-b:15).

underlined the role of agrobiology in insuring environmental protection and resource conservation when they set up curriculum and research projects (Buckland, 1989; Thériault et al., 1989), the CPVQ solely addressed the possibility of developing new crop productions when it engaged itself in agrobiology. The MAQ also emphasized this perspective as it justified the Plan on the basis of an increasing demand for organic products that actual production in biological agriculture could not meet.

After studies revealed that the market for organic products was increasing (Klaassen, 1986), and that food stores in Québec were importing 84% of their organic products from Ontario and New England (Gatien, 1988), the Minister of Agriculture asked the Economic Studies Branch to conduct a survey on biological agriculture for eventually releasing a policy.[66] A report entitled Situation and development of ecological agriculture in Québec (MAPAQ , 19888) set the grounds of future governmental interventions when it concluded that:

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66 After an opinion pool in 1986 revealed that 25% of consumers in urban area were ready to pay up to 30% more for organic products labelled as such and that Francophones shared an higher enthusiasm toward the consumption of organic products, the MAQ had its Markets Development Branch conducting studies on the market of organic products.

"The economic importance of ecological agriculture should not be measured by the number of producers but by its potential market. The MAPAQ must bring the biological farmers out of the marginal situation in which they were placed in the past years. It is not a matter of coopting, integrating or institutionalizing them. Rather, any support for their development must be tailored to their needs and the pace they have chosen. In that respect, any plan of intervention in ecological agriculture must be submitted to the different groups involved. (MAPAQ, 1988:111)"

From October 1988 to January 1989, the MAQ consulted different actors involved in biological agriculture and released its Integrated Plan of Interventions in August 1989. The goals of the Plan consisted of assisting the sector in organizing itself and providing technical expertise to farmers interested in converting their farm toward biological agriculture, a major priority for agrobiologists and governmental agents interested in agrobiology.

Consulted for the Integrated Plan in November 1988, supporters of biological agriculture asked for a certification system operated by the government (although two chapters of the OCIA still wished to remain independent). For them, the MAQ ought to recognize the role of agrobiology in providing food commodities of a superior nutritiousness and in respecting the agricultural environment; these issues constituted the guiding principles of their practices, the *raisons d'être* of the network they established. Agrobiologists had slowly eliminated from their agenda the idea of a regionally self-sufficient agriculture; although they continued producing on a small scale, some of them envisioned exporting organic products on foreign markets.

The MAQ avoided engaging itself in a debate over these issues which, according to the foreword of the Plan, only concerned a public environmentally aware and interested by healthy food. When it acknowledged the need to protect the market niche of organic products, the MAQ had to resort to a certification system; according to agrobiologists, this implied informing the public about the materials that each production processes introduced in the environment and in food commodities. However, the MAQ possessed a normalization system different from the one envisioned by agrobiologists.

4.2 The certification of organic products and agrobiological practices

Federal and provincial governments elaborated norms on food quality according to conventional agricultural practices.[67] Food analysis laboratories based their norms on the absence of toxicity and rendered irreversible the presence of toxic products in food commodities; only their concentration was subject to negotiations. Corporations and Consumption Canada, in charge of regulating labelling, marketing and advertisement practices, also gave little room for people fostering other criteria for food analysis. The grading system gave prominence to cosmetic rather than nutritional criteria while the labelling system concerned ingredients, with no information on the food production process.

Another characteristics of the normalization system was the focus on the end product. Proponents of biological

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67 For example, the use of pesticides helped the commercialization of foodstuff through the standardization of their quality, answering hygienic, organoleptic and economic requirements of consumers (Emond, 1975; 1976). Given that Health and Social Welfare Canada registered all chemical products used in the food industry, governments considered that pesticides represented no health risk unless they were used by farmers who did not respect the recommended dose or the time gap between spread and harvest.

agriculture saw monitoring of inputs rather than of outputs as a way to compensate such a situation and proposed certification systems for providing consumers with more information on the practices involved in producing, processing and distributing foodstuff (MacRae, 1989). A comparison of organic and conventional products based on the inputs used in each production process, rather than on food analysis from governmental laboratories, might have challenged actual agricultural and analytical practices on this issue.[68]

Producers and consumers of organic products wished that the MAQ would intervene for protecting the integrity of the label 'organic product' from opportunistic producers. Further, members of the MAB and of the ABQ demanded a governmental monitoring of inputs used in agricultural production. For the MAQ, disclosure about production practices went beyond current governmental regulations (MAPAQ, 1988). The sole possible governmental intervention concerned the protection of consumers' health regarding the products regulated by an independent normalization system, given that an organization

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68 This was also the case in the controversy over food irradiation when opponents required products treated under such practice be labelled as such; the federal government considered unnecessary the provision of such information.

defining and promoting more stringent criteria was responsible for applying them. In the absence of a knowledge base in governmental bodies for assessing and regulating organic products, three organizations set up their own certification systems (see 2.2.2.).

When it released the Plan of Integrated Interventions in Biological Agriculture, the MAQ realized that the multiplicity of appellations for food products impeded the collection of data on consumers requirements and an adjustment of demand and supply for organic products. Considering that the numerous organizations of agrobiologists hindered the communication for organizing concerted actions, politically and commercially, the MAQ financially assisted agrobiologists in forming a unique organization, the Federation of Biological Agriculture in Québec (FABQ)[69]. While the latter replaced the existing unions of agrobiologists, the organizations involved in certification were still active.

The MAQ set up a committee with the FABQ, the MAB and the OCIA for elaborating a certification system.[70] These

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69 The Provincial Union of Biological Farmers Reunited and other regional unions adopted the status of a federation for joining the UPA.

70 One of the chapter of the OCIA refused to adhere to the committee.

organizations insisted on the need to resort to an independent agency for applying governmental regulations related to the use of a unique 'organic label' for local and foreign products (FABQ, 1990). However, the MAQ had already prepared a program based on its policy for agri-food development which emphasized the creation of new markets for agricultural products with added value; besides organic products, it concerned food commodities from other specific agricultural practices or from specific regions.[71] The MAQ then needed a certification system flexible enough to embrace all these different products; it adopted a system of voluntary compliance where sectorial or regional organizations elaborated norms that their members had to respect.[72]

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71 While specific practices addressed products like grain-fed chickens, the notion of regional productions closely resembled the one used in the French wine industry, where regional cooperatives organized a system of *appellation contrôlée.*

72For the MAQ, the designation system constituted ",to some extent, the official guarantee that the product correspond[ed] to its label" (MAPAQ, 1990-a:3. *My emphasis*).

Agrobiologists first rejected that system as it slightly differentiated their practices from other ones.[73] Also, since the MAQ intended no enforcement procedures besides the ones already in place, the appellation system offered no control for organic products from other provinces and from the States. Finally, with the designation mainly concerning food products and not agricultural processes, the MAQ avoided the debate over the nutritiousness of food commodities.[74] Nevertheless, the MAB transferred its certification activities to a public body, the Agency for Controlling the Integrity of Organic Products; it could then received financial assistance from the MAQ for certifying agrobiologists and promoting the consumption of organic products. The ABQ and the OCIA continued operating their own certification system.

For some agrobiologists, the designation system remained inefficient in insuring the integrity of organic products,

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73All certified products would have a label entitled *Québec-Vrai* and a mention of their specificity: organic, grain-fed, etc..

74The MAQ also claimed that designation was not a matter of comparing the nutritiousness of the specific products and the ones grown under conventional practices, the latter being subjected to governmental regulations concerned by other issues, innocuousness and salubrity (MAPAQ, 1990-b) informing consumers about the nutritive value of food commodities, and revealing the production or transformation processes involved (Tétrault, 1990; Reid, 1991). In the absence of a common agenda within the community of agrobiologists, government possessed room for maneuvering in establishing a certification system; it also hindered the production of commensurability between the knowledge bases in food analysis. With different organizations promoting different certification system and standards for agrobiological agriculture, biodynamic, organic, and biological products appealed to different consumers.

In 1991, the MAQ evaluated the Plan for future interventions. Actors involved in agrobiology who, in 1989, considered certification as the top priority were now putting less emphasis on the issue. After having enlarged and protected a market niche, certification needed to be relativized; actual mechanisms sufficed despite the imperfection mentioned by some actors (Bélanger et al., 1992). At a national colloquium on sustainable agriculture[75], proponents of agrobiology counter-attacked

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75 In Canada, the federal-provincial agriculture committee on environmental sustainability defined sustainable agriculture as:

"an economically profitable agri-food systems which supply the healthy nutritious food that society needs while preserving and developing their opponents' argument about quality control, claiming that it was not a food safety issue any more but an economic and environmental one (Boutet, 1990).

Considering the steady number of farmers having their practices certified, agrobiologists and governmental agents considered that certification might contribute to the marginalization of agrobiology. To overcome this situation, the MAQ enlarged its support of agrobiology by considering it as a component of sustainable agriculture. It now linked resource conservation and the market of organic products.

After having measured the <u>foreign</u> origin of organic products, the MAQ maintained its discourse on self-sufficiency in food production. It later rephrased it in terms of a food commodities with added value. Although these discourses underlined the economic importance of biological agriculture and neglected claims from agrobiologists about the respect of the environment and soil life, the MAQ now overlooked previous concerns of yield measurements and supported the development of an alternative agriculture.

The legitimation of agrobiology involved the integration of biology in soil sciences, the use of compost as a soil

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natural resources and the quality of the environment for the future generations."(FPACES, 1990: ii).

fertilization and conservation practice, and the resort to agrobiologists for diffusing a set of integrated farming practices. Although it recognized the infrastructure of agrobiologists for distributing and certifying organic products, the MAQ distanced itself from their approach for analyzing food nutritiousness and for monitoring agricultural practices. The agrobiological community now possessed a material basis that insured its reproduction within the academic, scientific and governmental circles, in the agricultural fields and on the market shelves.

The agrobiologists enjoyed a certain autonomy for pursuing their development by having their core practices and institutions introduced in governmental policies and research organizations. They maintained their identity by having their farming practices recognized as an exclusive and integrated approach in agriculture. However, they barely succeeded legitimating their role in protecting the agricultural environment and offering healthy food, which constituted the basis of their involvement. While the Plan remained a mitigated support to agrobiology as it solely addressed the market share of organic products, the agrobiology network now possessed resources and institutions for producing knowledge in soil biology and agrobiology within governmental and academic circles, and for reproducing practitioners through the training of extension agents and farmers and the diffusion of agrobiological practices.

5.0 Conclusion

The objective of this thesis was to account for the legitimation of agrobiology. We saw that actual studies on the emergence of agrobiology neglected analyzing the content of scientific knowledge. Using Kuhn to understand the emergence of agrobiology as the result of problems encountered in conventional agriculture and solved by agrobiological practices is simplistic. An analysis of the content of scientific knowledge, and more precisely of scientific practices, allows the identification of the processes of scientific change occurring in agricultural sciences. This approach prevents an examination of scientific changes as a product of external constraints. This thesis describes how these constraints are translated in practices that are transformed by the gradual introduction of agrobiological entities.

The model that Kuhn has proposed for understanding scientific change presents inherent problems. First, Kuhn denies the existence of competing 'paradigms' during normal science. Chemical and organic fertilizations were part of competing paradigms that existed prior to the crisis in land degradation, in agronomy, in agrobiology and in forestry. Second, Kuhn's focus on language change obscured the role of practices and instrumentalities in the resolution of a scientific crisis. For instance, adopting a parameter like the nutrient content of compost remained insufficient for legitimating the composting practices of agrobiologists; other factors were at stake, like obtaining high yields, and, more importantly, possessing theoretical entities and experimental practices in soil biology for assessing knowledge claims about compost and organic fertilization.

The third problem is related to the internal regulation of the scientific community. Although one might concede that scientists subject their work to their own criteria, they may nevertheless be influenced by external factors. For example, because of the discontent of rural communities, manure was brought in the experimental fields. More importantly, researchers modified their theoretical practice when they were unable to resolve problems related to a declining soil productivity; unlike manure management, soil degradation had to be internalized. While Kuhn is wrong in assuming the independence of the scientific community, one should examine how scientists translated external constraints in their practice.

This thesis has presented the development of two bodies of knowledge for understanding the legitimation of agrobiology - a process that involved two distinct phases. First, it required conceptual changes where networks of practices in agrobiology and in soil sciences resorted to common experimental tools and theoretical entities. Secondly, it involved institutional changes where ministries of agriculture relied on agrobiologists for diffusing soil conservation practices.

While incommensurability prevented the two networks from sharing a knowledge base and commonly defining agricultural problems, incremental changes in the experimental practices of soil scientists led to the coexistence of 'conventional' and agrobiological entities in scientific explanation. With the manure management crisis, soil scientists added another fertilizing material to the chemical fertilizers they already used in their experiments. After having enlarged their framework of analysis and included biology in their explanation of soil productivity, they studied the role of humus in building the soil structure and the role of microorganisms in providing nutrients to the crops. These entities, and the experimental tools required for their analysis, paved the way for the study and the use of compost in soil sciences.

For soil scientists, resorting to compost was not tantamount to supporting agrobiology. Different networks defined the identity - agrobiological, industrial, agronomic-and the function - crop fertilization, biomass conversion, resource conservation- of compost and composting practices. Agrobiologists set up different mechanisms for producing and transferring agrobiological knowledge: on-farm demonstration, collaborative research, production clubs. They combined composting to crop rotations, biological and mechanical pest control, and other farming practices that avoided synthetic chemical compounds. They called on farmers to adapt, rather than adopt, agrobiological practices to the specificity of their farm and, consequently, to act as experimenters themselves. By performing these social practices, they maintained an agrobiological identity to compost and to composting practices. Consequently, they legitimated their network.

A central concept in this case study was the network of practices. The network referred to (1) a combination of practices defining their identity and (2) a community of practitioners maintaining this combination of practices and securing the growth of the network. Practices involved the different interactions with the material world performed by the practitioners. Resorting to the network of practices helped understanding how a practice maintained the identity from its original network even when it became entrenched in a different network. The focus on scientific practices exemplified the self-reinforcing nature of phenomena production in preventing the introduction of new theoretical entities and scientific explanations; it also presented the conditions under which material constraints forced a revision of scientific concepts.

Resorting to the concept of the network helped overcoming a problem inherent in the study of incommensurability: the comparison between two bodies of knowledge that are incommensurable. In this case study, the problem was even more acute since soil sciences relied on an elaborate theoretical foundation while agrobiology consisted of a number of core practices. Instead of presenting symmetrically the theories, experiments, and institutions of each body of knowledge, the thesis has presented their cognitive and social organization. From that description, one can follow the changing context and content of each network and how, when new entities are integrated into a network, incommensurability dissolves.

The approach nevertheless remains asymmetric by neglecting certain features of one network. Unlike their counterpart in agrobiology, the market for conventional agricultural products and the farming practices of conventional farmers were not thoroughly described. A related problem is the relationships between the rules defined by soil scientists and their application by conventional farmers. With fertilizer dealers acting as intermediary between soil scientists and conventional farmers, calibration studies may be peripheral to the fertilizing practice of farmers; the fertilizer dealer has an important discretionary power when interpretring fertilization grids and defining fertilizer requirements. A field study might have clarified this point. It remains that fertilizer dealers and soil scientists worked within the same network and reinforced barriers for the introduction of organic fertilization and agrobiology.[76]

Another aspect of this thesis that could benefit from a field study concerned the number of agrobiologists or farmers applying agrobiological practices. As mentioned in section 4.2., the number of certified organic farmers stagnated around three hundred. But agrobiologists only resorted to certification for marketing reasons. Interested in lowering the production cost, dairy farmers converted to agrobiology although they have no market incentive since milk is collected and distributed in bulk; dairy farmers also

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76 This thesis focuses on agricultural research and since, in Canada, 7 percent of the research and development in agriculture is performed by industry (Hayes, 1973), the author has paid little attention to the role of the agri-chemical industry in maintaining the conventional approach in soil sciences.

possessed the advantages of being involved in mixed farming activities, with animal and crop productions, on farms of a medium size (Hébert, 1989-c).[77] The absence of data on the number of agrobiological dairy farmers makes an assessment of the importance of agrobiology more difficult. This thesis compensated this lacuna by providing a description of the strength of the network in agrobiology, its potential for producing knowledge in universities and governmental laboratories and for reproducing farmers, extension agents and researchers converted to agrobiology.

Finally, the case study, by focusing on the development of agrobiology in Québec, may have left the impression that actors have operated in a closed circle. Although an analysis of external sources of legitimacy for agrobiology may overcome this deficiency, the reader should note that agrobiologists sometimes resort to foreign scientists in

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77 Between 1941 and 1971, the number of farmers decreased from 154 669 to 61 257; the number of dairy farmers further decreased by 50% between 1970 and 1980, with production remaining stable (Guay et al., 1992). While 15.6 % of the dairy farms have more than 50 dairy cows, 53.9 % of them have between 25 and 40 dairy cows and are of medium size (ACSI-BIOREX, 1989). A herd of 40 cows constitutes an economic threshold; when that number is exceeded, the man-power and capital requirements are dramatically increased (GREPPA, 1989).

promoting the development of agrobiology in Québec.[78] Agrobiologists from Québec maintained contacts with the international agrobiological community; researchers from France, Switzerland and Germany were sometimes invited at conferences on agrobiology.(Bourgignon, 1989). In the absence of technical literature published in Québec, agrobiologists relied on foreign literature in the earlier years of the emergence of agrobiology in Québec; with the publication of the first technical manual on composting by Petit, they resorted to their own literature and experience to promote the development of agrobiology. The most notable external source of legitimacy was the foreign countries that provided organic foodstuffs to the domestic market in Québec and that also possessed certain market niche for organic products grown in Québec.

This thesis provides interesting hindsights for science policy, and for science and technology studies. Agricultural science falls within the category of applied science; the relationships between incommensurability and legitimation may differ in a context of basic science where the scientific community is more immuned from external influence. Facing a

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78 An analysis of the citation pattern of scientific articles on agrobiology may clarify the role of external sources of legitimacy for the development of agrobiology in Québec

declining soil productivity, the agricultural community and, to a lesser extent, the governement validated the knowledge of soil scientists and required a different approach in soil fertility. The smaller number of external actors in basic science may limit the extension a network for challenging the authority in place.

In a context of limited resources, science policy-makers concerned by the idea of progress abandon a research agenda to accelerate another one. However, the selection of a research agenda should not lead to the disappearance of alternative ones. Given the uncertainty of scientific knowledge, the presence of alternative research agendas is useful for absorbing scientific and technological developments necessary to alleviate unforeseen problems. Alternative research agendas may also provide a common knowledge base for comparing and judging contradictory claims in socio-technical controversies. Questions remain as to how much resources should be provided for the maintenance of different research agendas and as to who should be comparing contradictory claims.

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