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Sustainability research: Organizational challenge for intermediary research institutes

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ABSTRACT

The agricultural sustainability challenge is often formulated in terms of meeting the increasing demand for food of a growing and wealthier world population while simultaneously reducing environmental impacts. Strategies to meet this challenge include increasing agricultural yields, saving land and diverting agricultural produce from use for feed and fuel. The paper compares such strategies based on natural sciences with alternatives captured under the umbrella of sustainability sciences, based on systems and mixed sciences approaches. Theoretical and methodological foundations of various branches of sustainability have been developed over the last decades at academia, but although experimentation -putting theory into action- has been carried out a in The Netherlands to a considerable degree, this has hardly led to institutional change of research constellation itself. It is argued that intermediary research institutes by their position in between academia, practice and between government and society are in principle well positioned to incorporate sustainability science. This requires boundary management beyond the traditional boundaries of biological and technical disciplines and their fields of application and retention of methodology and knowledge within with units of scientists with complementary knowledge and skills. To become effective doing sustainability science can probably only be achieved after a prolonged period of experimentation and evaluation, while the shared base of theories, methods and networks form the core of such a knowledge system, as contrasted to disciplinary groups.

1. Introduction

1.1. Scope of the paper

Research institutes are characterised by their position in between universities and practice. Gulbrandsen [1] characterises them as hybrid organisations on the dimensions private-public and science-non science. Often they have been founded as governmental institutes to enhance national competitiveness in a specific field of application [2]. This complies also to the agricultural research institutes in the Netherlands, Some were founded as early as the 1890's as governmental institutes with a focus on quality control of agricultural produce. From the 1980's orientation shifted from purely publicly financed institutes to contract research organisations with governments (EU, national and lower), collective financers and commercial organisations as commissioners. Over the years agricultural research evolved with contemporary problems, successively characterised by quality control, improving production efficiencies, abating undesirable side effects of production (e.g. environmental contaminations and impaired animal welfare) and -relatively recently- complex sustainability problems. For all their reorganisations, privatization and mergers the institutes tend to maintain their original characteristics in research philosophy (positivist-reductionist) and fields of application (such as animal breeding-and dairy farming).

In this paper it is argued that in the search for sustainable development intermediary research institutes, by their hybrid position and orientation on societal problems are in principle well positioned to take up the challenge of addressing complex sustainability problems. This in contrast to universities with their disciplinary organisation and orientation on international scientific disciplines. Notwithstanding the confrontation with sustainability problems and adaption of sustainability oriented research in intermediary research institutes, including those in animal sciences, remains a challenge. The institutes tend to preserve functions, structures and scientific ontology's of modernisation and show limited incorporation of structures and functions for doing sustainability research [1,3]. This despite the philosophies, theories, heuristics and analyses of experiences that have been built up during the last decades in academia to address complex sustainability problems. This paper reviews the nature of the sustainability

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challenge for agriculture and explores strategies to meet the challenge and explores institutional change needed to address complex sustainability problems by intermediary research institutes, with a focus on agricultural institutes in The Netherlands.

1.2. The sustainability challenge

Population growth in combination with increase in wealth has been accompanied by higher demand for natural resources and increased impacts on the environment. Only recently awareness emerged that natural resources could be depleted and burdening the environment could threaten the conditions which allowed man to evolve and live [4,5]. Ecosystem services, availability of natural resources and agricultural production to provide sufficient food are increasingly under pressure as shown by analyses on the global level of climate change [6], biodiversity [7,8], land use [9–11] and freshwater availability [12]. Looking ahead a further increase in world population to 9-10 billion around 2050 is expected, which in combination with expected on-going economic growth will - with unaltered systems of production and consumption - strengthen the trend of depletion of resources and threaten ecosystem services. Estimates by Röckstrom et al. [4] indicate that at present global boundaries for stability of three major systems have already been transgressed. This applies to 1, climate change (by emissions of greenhouse gases and radiation forcing); 2, loss of biodiversity (by perturbations of local ecosystems); and 3, the nitrogen cycle (mainly by agricultural losses of fixed atmospheric nitrogen and the effects of resulting N-compounds in terrestrial, aquatic, atmospheric and troposphere systems). The phosphorus cycle (by rate of depletion of mining resources and flows into oceans resulting in oxygen depletion), fresh water use system (by human use) and land use (by conversion for crop land) approach threshold levels. Some of these systems are truly global in nature (climate, ozone, ocean) others are to be seen as cumulative effects of affected local and regional systems [13].

Agriculture, as compared to energy, mobility and housing systems, is the human activity that has largest impact on natural systems by use of land and water and effects of various inputs on the environment [14]. The agricultural challenge is often formulated as producing food for 3 billion more and probably wealthier people within two human generations and simultaneously reducing effects on environmental systems.

2. Strategies

2.1. Strategies based on natural sciences

Strategies have been proposed by Foley et al. [15] and others [5,11,14,16,17] to meet the agricultural challenge. Such strategies emphasize a combination of the increase of production per hectare (Strategy 1), avoidance of further conversions to cropland and increase of resource use efficiencies (Strategy 2) and making more food available by shifting crop production from the use for livestock and for fuels and reducing wastes (Strategy 3) [15]. Accepting this combination of overall strategies, the question remains how on the local and regional level such changes can be realized and what type of research is needed. The more so while agricultural interferes with many other activities (e.g. housing, transportation, water supply) and settled interests to provide such services. In the next paragraphs these strategies are discussed shortly.

2.1.1. Increasing production per hectare

Scientific literature indicates that there are ample possibilities to increase agricultural yields. These are based on estimates of increasing the maximum yield potential of crops (expressed as yield per hectare and year) and animals (expressed as production per animal and year or as feed conversion rates) and on closing present yield gaps. Future studies on yields (e.g.[15]) indicate that potential maximum biological yields of crops and animals could, dependent on type of production, be increased by 15-50% by 2050. Such predictions are founded on extrapolation of past trends and on promises of new technologies based on scientific break trough's [18].

Analyses of yields in various parts of the world, based on FAO-data (FAOSTAT), show large variations. Often these levels of yields are well below the yield potential that could be obtained by supplying all growth factors timely and at a sufficient level [19]. These yield gaps indicate that there is considerable potential to produce more food by implementing already existing technologies.

2.1.2. Avoidance of further conversions to cropland and increase of resource use efficiencies.

Borlaugh [20], in an overview of the effects of the Green revolution, reminded that by introduction of various technologies, including fertilizers, crop protection, irrigation and new breeds, in the period 1950 to 1997 the demand for cereals of a doubled world population was produced by using one third of the agricultural land that otherwise would have been needed. This statement can be taken as the starting point for the dispute on land sparing by intensification of production versus maintaining higher levels of biodiversity at lower levels of production [10,16]. A central point in this dispute is the idea of resource use efficiency, stating that sufficient supply and control of the first limiting growth factor allows higher yields without increasing losses per unit of produce [21]. This approach has been proven to be fruitful in tuning nitrogen use efficiencies in crop production [17]. But resource use efficiency is scale (including economic, biological, temporal and spatial scales) and scale level (e.g. cell, organism, field or herd) dependent making optimizing resource use efficiencies across scales and levels extremely complicated [22]. Focus on strategies to increase yields as means for land sparing for landscape and nature takes several aspects not into account. This applies to the contributions to biodiversity of agricultural land itself, patterning of agricultural land with landscape and nature elements [23] and to effects agriculture on "land use" elsewhere by direct and indirect influences on biodiversity [10,11].

In addition more systemic effects should be taken in consideration. Before the industrial era agriculture was predominately a farmer's affair. Gradually interdependencies were formed with knowledge, farm supply and processing industries and regulatory institutions. This increased complexity could be described as agro- industrial complexes, in plural because they evolved locally and nationally. Yield improvements require inputs and control which are provided by the agro-industrial complex, which state of development is linked to general industrial development, including agriculture productivity, and standard of living [16]. Kastner et al. [14] found that these linkages led to a fairly constant need of about 0.2 ha of agricultural land per capita. Thus increases in yield have been compensated for by increase of using more nutrients, apart from the possible increase in demand for other agricultural produce and agricultural services [14]. Unless the link between population and land use is broken it seems hard to meet the demand for agricultural produce for a growing global population without further conversion to croplands.

2.1.3. Making more food available by shifting crop production from the use for livestock and for fuels and reducing wastes.

Strategies to meet the future demand for agricultural produce [15] involve shifts in land use and of plant crops from the use as livestock feed and for fuels and avoidance of losses. Estimates indicate that at present 2/3 of cropped land (including grasslands) are used for animal feed and about 3-5% for fuel [24]. Shifts in use can be obtained by predominately using crops and crop residues that are not suitable for human consumption for feed and fuel and by changes in human diet and avoidance of losses. However, present insights show that increase in wealth is strongly associated with a growing demand for agricultural produce and especially those of animal origin [25]. Furthermore, man consumes neither dry matter nor animal live weight, the predominant units of agricultural scientific analyses. Human needs are variable and might be expressed in variety of terms dependent on lifestyles, local cultures and values. A scale of human needs for agricultural produce might be constructed, with at the lower end food needed to provide nutrients for a healthy diet and at the higher end food and other agricultural products needed to maintain a life style. For all the none-nutrient use of agricultural produce, this is all use that goes above satisfying basic nutritional needs, the term agricultural life style services is suggested. However, what can be designated as fulfilling nutritional needs versus providing lifestyle service depends on the standard of living. Under subsistence conditions many people are dependent on animal produce, whereas in more wealthy situations animal and crop production fulfil needs that go beyond the nutritional requirements and should be associated with maintaining life styles. Examples include social functions of food but also the possession of companion animals (often including horses), ornamental plants, coffee, tea, alcoholic–beverages and drugs, such as tobacco.

2.1.4. Realization of strategies.

The combination of strategies, as proposed by Foley et al. [15] and discussed above, are based on analyses according philosophies of natural sciences. The knowledge provided informs society and could be used in societal and political domains to solve the complex underlying problems. On a lower scale (western) agriculture has been large shaped by interaction between techno-scientific thinking, focusing on yield improvements, largely neglecting environmental as well as societal risks [26]. The main indicators for production efficiency, including yield, feed conversion rate and resource use efficiencies guide development in farming and of agro-industry, while increasingly taking into account the unwanted side effects on nature and society. Integrated assessment (e.g. [27,28] estimate the effects (e.g. loss of biodiversity and contributions to climate change), on a specific spatial scale (e.g. region, nation, world) thus informing notably policy makers at the corresponding governance level. A similar function has life cycle analyses making it possible to compare the environmental footprint of products with similar functions or similar products produced in different ways (e.g. [29,30]). Such aggregated analyses are indispensable in giving insight and guidance for action and reflexivity. However, by being formulated in general and objective terms they are typical products of how agriculture has evolved and suggest a “one size fits all” solution. They tend to neglect geographical and cultural variations, e.g. (changes) in attitude towards animals. Furthermore, such analyses do not take the societal boundary condition of maintaining or improving social stability and equity into account. Neither do they give an indication on how the societal shift to more sustainable production and use of agricultural produce can be achieved. These analyses inform but do not provide solutions for institutional change, including changes of human lifestyles. In this respect these analyses seem to rely on the power of persuasion of telling the “objective truth” not taking in account the complexity of interactions between human and natural systems [31]. The present situation is produced by human actions and embedded in societal systems. Changes required to meet the sustainability challenge depend on changes in human action, individually as well as collectively [13].

2.2. Mixed sciences strategies

2.2.1. Sustainability science

Over the last decades research philosophies and approaches have evolved which include the societal domain. Seminal in this respect was the plea of Gibbons at al. [32], to involve stakeholders in the process of knowledge production to obtain not only “scientifically reliable knowledge but also societal robust knowledge”, often referred to as Mode II Science. Though Mode II Science did not focus explicitly on sustainable development, it contributed to research approaches that aim to produce knowledge in the context of its application. Since its publication a growing body of knowledge (philosophies, heuristics, working methods, evaluations etc.) has evolved, notably in academia, with emphasis on search for sustainable development and aim to supplement the natural scientific strategies (for an overview see [33]) with insights from social and systems sciences. Their main common characteristics are 1. taking the search for sustainability as a normative scientific stand, 2. transgressing disciplinary borders by including various scientific disciplines (interdisciplinarity) and interactivity with stakeholders and other societal actors in the analyses and design (transdisciplinarity), 3. taking a systemic perspective by focusing on analytical levels of coupled technical, environmental and social systems, their interactions and dynamics of (deliberated) change and 4. aiming at societal learning. The approaches are here captured under the designation “sustainability science”. The designation sustainability science itself is rooted in the USA [34], but increasingly recognises similar developments elsewhere [35], including transition management (TM) [36] and approaches of coupled ecological and social systems, (SES) [37]. The approaches are founded on a systems approach and take complexity and non-linearity into account. A definition of sustainability science has been formulated as “an emerging field of research dealing with interactions between natural and social systems, and with how those interactions affect the challenge of sustainability: meeting the needs of the present and future generations while substantially reducing poverty and conserving the planet’s life support systems” (cited by [38]).The core of sustainability science has been described as “. . .sequential analytical phases of scientific inquiry [.] will become parallel functions of social learning, which incorporates elements of action, adaptive management and policy as experiment” (cited by [36] p3). Sustainability science draws upon various sources of knowledge, including natural sciences, social sciences, complexity sciences and also on local and tacit knowledge. TM and SES take an explicit systems perspective by focusing on analytical levels of coupled technical-social and environmental-social systems, respectively, their interactions and dynamics of change.

2.2.2. Transition management

Transition management takes socio-technical systems as core unit of analyses. Socio-technical systems are functional combinations of social and technological actors that provide goods and services [39]. The basic research question is whether such systems can deliberately be changed to sustainability [40]. The complexity of functional systems (such as energy and food production or their sub-regimes) is captured in the definition of socio-technical regime:”. . ..a rule-set or grammar embedded in a complex of engineering practices, production process technologies, ways of handling artefacts and procedures, ways of defining problems; all of them embedded in institutions and infrastructures” [41].

Transition management focuses on deliberate change of a regime for sustainability. A part of the process is defining the common sustainability goal by envisioning, creating and fostering innovation niches. In this approach the Multi-Level Perspective (MLP) has become an important analytical framework. It connects the rearrangement of socio-technical regime, at one side to external changes, i.e. in the surroundings which envelope the regime (”landscape level”) and at the other side to innovation initiatives (“niche level”). The core idea of the MLP is that system innovations are shaped by interaction between three levels: the socio-technical landscape, the socio-technical regimes and innovation niches [39].

2.2.3. Socio-ecological systems

Socio-ecological systems (SES) takes coupled ecological (ecosystems) and social systems as core unit of analysis. SES takes a focus on spatial space of e.g. a water catchment or an (administrative) region [37]. The basic research question of SES is how the system can increase the capacity to deal with perturbations while maintaining or improving its ecological and social functions (resilience). By a focus on maintaining ecosystem functions and governing common resource pools SES inherently aims at sustainability (e.g.[42]). The central analytical framework is the adaptive renewal cycle, which postulates that systems undergo subsequent phases of exploitation, conservation, release and reorganization. Such cycles are speeded up or slowed down by being nested in systems on larger spatial scales with slower cycles [36].

TM and SES are complementary as areas (“environmental systems”) provide the resources, (e.g. for water, agricultural production) for various socio-technical regimes such as growing or extracting the resources, transportation, processing and marketing. In their approach TM and SES differ in their systems perspective. TM aims at change of unsustainable systems to envisaged sustainable systems by weakening the resilience of existing regime and empowerment of the alternative, whereas SES focuses on strengthening the resilience of ecological as well as social functions [43].

2.2.3.1. Dutch examples of emerging sustainability research.. In the period that theories on sustainability science developed, researchers at intermediary research institutes were confronted with questions addressing complex sustainability problems. Some of them were inspired by theories on sustainability science and recognized that the usual disciplinary scientific approaches were inadequate by giving at best a partial and limited solution to the problem. In many instances these researchers started experimenting with alternative approaches including visioning and stakeholder involvement. Because of the emphasis on action research this experimentation is here referred to as “’doing” sustainability science.

Table 1 summarises three examples of such experimentation that emerged in The Netherlands and which could be considered as attempts of doing sustainability science. As descriptors we took as main characteristics visioning and the anticipated integration of activities [33]. Because research largely depended on collective financing and cooperation with governing bodies these are mentioned. Additional characteristics and descriptors can be found in the literature cited.

Of these developments NFW is regionally bound and bears characteristics of (an attempt for) strengthening resilience of the socio-ecological system. Roundel was based on ideas about TM [46]. Although regionally bound, this applies also for NGB which was elicited by visions of industrial agro-production parks with reduced environmental footprint by combining different agricultural activities [46]. These examples are characterized by multiple interaction between research organizations, local actors, NGO’s and governmental bodies during all phases (start, process and evaluations) and financial support by public funding. They form a chain of activities and projects in which the next step was not planned and could not be predicted. Technical evaluations of yields and production efficiencies at the farm level showed similar yields as in main stream agriculture. Notably societal values as landscape and nature preservation (NFW), animal welfare (Roundel) and local embedment were improved (NFW and Roundel). Most noticeable, however, are the emerging institutional structures towards more local governance of landscape and nature by farmers (NFW) and to constellations of farmers, supply chain partners including retail, animal welfare organization, marketing products with increased animal welfare for a premium price (Roundel). These emerging systems judged show that societal learning has taken place and rearrangement of actors achieved. NFW in the combination of dairy farming, nature and landscape governance is achieved together with strengthened local embedment. NGB probably has great promises by reducing environmental emissions from the synergies between the various activities, but meets societal resistance due to its size and industrial character [47] and has as yet not been realized.

3. Institutional change for sustainability research?

3.1. Doing sustainability research

Sustainability science has shown rapid development over the last decade. Within these fields the academic side of description and analyses, aiming at getting a better understanding and formulation of theory is relatively well developed as witnessed by academic sustainability educational programs, chairs at universities, international networks, congresses and scientific journals [49]. This applies also for the Netherlands were the KSI-network coordinated academic sustainability studies [40]. This in contrast to “doing” sustainability science aiming at supporting processes of transformation towards sustainability.

Within The Netherlands experimentation with sustainability science, has been performed on a considerable scale, also in the agricultural domain (see box and [50]). The research has been conducted by intermediary agricultural research organisations as well as by temporary governmental organisations such as Transforum [51] and Innovation Network [52]. The latter organisations linked entrepreneurial innovation with universities and research institutes aiming at sustainable development and were characterised by Smits and Kuhlmann [53] as examples of emerging systemic innovation (policy) instruments. Such instruments focus their analyses and actions on a system of change (e.g. a socio-technical system). The examples in Table 1 were all partially supported by one of the systemic innovation instruments mentioned. In all cases research communities evolved, that transgressed existing institutes and research domains and incorporated elements of knowledge systems for sustainability research. The outcomes of NFW and Roundel projects showed changes in the configuration of technologies and actors. However, elements mentioned in the combined strategies by Foley et al. [15] were not incorporated. This probably because the actors involved in the projects did not formulate their problem definition and shared vision of solutions in terms which–implicitly or explicitly- aligned with those strategies. This indicates at one hand that sustainability science opens up additional solutions which incorporates institutional changes (i.e. changes in culture, infrastructure, networks) for sustainable development, and at the other hand that incorporation of actors beyond the context remains a challenge.

3.2. Features of effective systems doing sustainability research

Analyses of sustainability projects [54,55] and of systemic innovation instruments [53] indicate functions and structures of effective organisations for ‘doing’ sustainability science.

An essential feature of sustainability science is exploring the boundaries between communities with different views on what reliable and useful knowledge is. Such boundaries can be discerned between scientific disciplines, between science and

Table 1
Examples of sustainability research.

Descriptor	Northern Friesian Woodlands (NFW)	"Roundel" laying hen husbandry	Nieuw Gemengd Bedrijf (Novel Mixed Farming; NGB)
Guiding vision	Regional governance to combine dairy farming with landscape and nature protection. Based on explicating farmer's values.	Design of laying hen unit with large interpretive flexibility arisen from an interactive design process based on needs of hens, farmer and citizen.	Design of combined agricultural activities on an industrial scale aiming at reduction of environmental emissions.
Integration strived for	Dairy farming and landscape and nature preservation.	Needs of hen, farmer and citizen in laying hen husbandry	Horticulture, pig farming, broiler production, manure treatment, slaughterhouse and energy production
Main governance levels involved	Farm, municipal, provincial.	Commodity board, national government.	Farm, municipal, provincial and national governments.
Status in 2012 (years after start)	Limited local self government by farmers in environmental cooperatives. (21)	Innovation niche. (11)	Building plans approved by municipal and contested by citizens and NGO's. (11)
Physical realisation	Cooperatives of 900 dairy farmers with 50 000 ha in 5 adjacent municipals.	Three poultry farms with each 30 000 layers with premium supply chain based on improved animal welfare and local embedment.	Not realized yet.
Critical factor(s) for stabilizing and empowerment	Farmer's income for landscape and nature preservation.	Premium price paid by consumers for sustainability products.	Local embedment.
Dominant systems approach[1]	SES	TM	TM
References	[44]	[45,46]	[47,48]

[1]Systems approach is given in hind sight as TM and SES were at the time not yet available as theories to guide action oriented research.

policy, entrepreneurship, civil society etc. Effective boundary management aims at participation, creating boundary objects, with accountability in principle to both sides of the boundary. Clark et al. [55] emphasize the importance of communication with stakeholders, translation of the different languages used by stakeholders, experts and decision makers to bridge their language gap, e.g. by boundary objects and mediation of conflicts by transparency and active mediation. From these functions they derive three institutional features of organisations that "link knowledge to action for sustainability": 1. treating boundary management seriously, 2. dual accountability of boundary managers and 3. use of boundary objects. Discussing the functions of systemic innovation instruments, Smits and Kuhlmann [53] mention in addition to boundary management ("management of interfaces"); the constructing and deconstructing (sub)systems; providing a platform for learning and experimenting; providing an infrastructure for strategic intelligence and stimulating demand articulation, strategy and vision development. To perform also these functions requires additional expertise (e.g. about strategy, visioning) and the capacity of extracting knowledge from experimentation and providing an infrastructure. Functions and expertise that can only over a considerable period of time (6-9 years was found by [56]) be realised in a knowledge system.

3.3. Constraints

Despite the noticeable scale of experimentation, continuity in the effort of "doing" sustainability research is hampered and therewith the built up of institutions and capacity. Several factors have been identified that contribute to the relative inertia of institutes to adopt sustainability research. The hindrances can be differentiated to the policy level, level of research institutes and level of the individual researcher.

3.3.1. At the policy level

Policy makers, although supporting and participating in experiments with sustainability science tend to value objective scientific truth and useful knowledge for their own domain, more than societal learning. This dualism in combination with discontinuation of systemic innovation instruments and sustainability programs that elicited action oriented knowledge systems prevents such research of gaining maturity. It maybe that appropriate institutional arrangements and its rules can be designed when needed, but to be effective rules have to be maintained and expertise and understanding built up against many challenges. Grin et al. [3] identified the major hindrances, including 1. stakeholders and researchers are uncomfortable with their roles of "co-learners" 2. researchers have strong inclination tom their home discipline 3.disciplinary differentiations between institutes 4. anticipation of stakeholders upon results as being too expensive or leading to new restrictive rules. They conclude that an institutional arrangement for doing sustainability research was insufficiently capable of creating a space for leaning by its embedment in the existing disciplinary institutes.

3.3.2. At the level of institutes

Gulbrandsen [1] emphasizes that intermediary research institutes by their organisational position- are capable of creating space between private (entrepreneurial) and public (governmental) and between scientific (academia)- and non-scientific (practices) spheres. He adds by being intermediate the legitimacy of research institutes is under pressure. From the academic side by not being scientifically independent, from the civilian side by being interwoven with their sector, from the public side by being bureaucratic and from the private side by producing knowledge that is not applicable in (their) practice and by unfair competition on the research market. This also illustrates the tensions associated with adopting sustainability research. While by default historically capable of creating learning spaces in their own combination of discipline(s) and fields of application, they are rooted in and are still associated with a specific (sub)sector of application and a specific types (biological and technical) of knowledge production [3]. An ambition to address complex sustainability problems demands an extension of their network of actors and expertise and capabilities. Consequently the boundaries of their original legitimacy and credibility are blurred. Furthermore, by being increasingly dependent on competitive funds ("the research market") Organisational boundaries that used to delineate separate domains become at the one hand weakened because of need for additional expertise to address complex sustainability problems and at the other hand strengthened because they become competitors for financial contracts.

3.3.3. At the level of the individual researcher

Researchers at research institutes are confronted with complex sustainability problems for which they were not trained. Furthermore institutes have become contract research organisations. A situation which easily leads to a diversity of project activities. Both the shift from disciplinary problems to complex societal problems as well as the increasing dependency on market and managers could contribute to confusion of the researcher about his/her professional identity. No wonder many researchers incline to take their disciplinary home group as main reference in their work [3]. This the more where literature indicates that trans disciplinary research work could have negative impact on career advancement. Never the less many researchers are inclined to do sustainability science. Analysis in a university context revealed that especially researchers with a concern about the societal utilisation of research results were inclined to interdisciplinary research [57].

3.3.4. Competences.

Based on an inventory of competences developed at university sustainability educational programs, Wiek et al. [48] list competences for sustainability research. They distinguish five key competences with each their theoretical concepts, methodologies and classic peer-reviewed literature. Here the key competences are given with an example of a concept or a methodology: 1. systems thinking (e.g. concept of resilience) 2. anticipatory competence (e.g. methodologies of envisioning and back casting), 3. normative competence (e.g. multi-criteria assessment), 4. strategic competence (e.g. concepts of transition) and 5. interpersonal competence (e.g. concepts of inter- and transdisciplinarity; participatory methods). These competences are in line with observations of Dutch system innovative projects showing that access to influential networks and agency to enrol stakeholders are essential [52]. Furthermore knowledge and access to a wide range of knowledge is needed, including sufficient insight in philosophy of science to understand and appreciate the various sources of knowledge [58].

4. Conclusions

Theory and methodology have been built over de last decades on how to address complex sustainability problems, however, predominately in academia. In the Netherlands considerable experimentation with 'doing' sustainability science has been performed, this includes construction of temporary knowledge arrangements to stimulate boundary work as well as experimentation by researchers of intermediary agricultural research institutes. By being intermediary between science and practice as well as in between government and society, intermediary research institutes seem well positioned to take the challenge of addressing complex sustainability problems. However, in doing so they are hampered by their original place in division of disciplines and corresponding fields of application.

To meet the challenge of doing sustainability research requires for organisational units shifts in several aspects, including:

- traditional domains of application and disciplines should be broadened to comprise functions, features and human capacity of doing sustainability research.
- complementarity of disciplines (including technical, social and systems) to build expertise and understanding of doing sustainability research.

Organisational units should shift their focus from discipline or single domain of application to a mutually understood approach based on sustainability science(s) and a specific context striving for sustainable development. A structure that can probably only be obtained by dedicated experimentation and learning and retention of lessons and results over a longer period of time.

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