Coupled Performance and Change in the Making

Prof. dr *ir.* Cees Leeuwis

Inaugural lecture upon taking up the post of Professor of Knowledge, Technology and Innovation at Wageningen University on 6 June 2013

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Esteemed Rector Magnificus, colleagues, students, ladies and gentlemen,

It has become almost a tradition in our section to have a second inaugural address. In the past, Professor Niels Röling and Professor Cees van Woerkum did that as well. I would like to believe that this relates to the lively history of our field of study, as represented in Figure 1.

Figure 1. Timeline representing the history of the groups that currently form the section Communication, Philosophy and Technology – Centre for Integrative Development.

As can be noted, the new Knowledge, Technology and Innovation chair is a merger between two streams. The oldest originates from the Extension Education (Voorlichtingskunde) chair that was established by Professor Anne van den Ban in 1964. Its basic mandate was to study knowledge and technology transfer , with a clear undertone of generating applied knowledge that would help to make such processes more effective. The second stream is the Technology and Agrarian Development chair that was created in 1993, following more than 8 years of pressure from critical left wing student groups, and especially the 'Imperialism Collective' (het Imperialisme Kollektief). This anti-imperialism group tended to make a neo-Marxist analysis of international relations, emphasizing processes of dependence and exploitation , in which science and technology were seen to play a facilitating and suspect role. The mandate given to this chair, to which Professor Paul Richards was appointed, was to "critically assess knowledge and technology development and transfer in developing countries". In the eyes of the left wing students, the 'extension' stream -to which I belonged at the time- was certainly not critical enough. Interestingly, the then Communication and Innovation Studies chair was not even mentioned in the long list of relevant groups to liaise with that was part of the original profile, despite the obvious similarity in object of study. Apparently, the perspectives employed and questions asked were too far apart.

So why are science and technology so often contested?

The brief history outlined above should lead us to ask the more general question of why we often witness such societal tension around the products of science and technology, and the processes through they are developed. This was the very topic of an essay writing contest that our internal news magazine Resource organised in 2012 in the aftermath of external critique on how Wageningen University and Research centre had reported on the blessings of milk consumption, and the causes of high mortality in bee populations (Volkskrant, 2011a, 2011b).

Reality reduction

Student Esther Brouwer won the essay contest. In essence her argument was that science tends to reduce reality to what is measurable and quantifiable, so that meanings and values get lost in scientific representations (Brouwer, 2012). She used the example of a common dandelium (Taraxacum Officinale), observed by a scientist. In her essay she makes the scientists think about the beauty of the dandelion, and describes the emotion experienced by him when observing it in the context of wind, sunshine, smell, the sound of birds, and the memory of his grandfather who also loved dandelions. Yet, when the scientist starts measuring, the dandelion may well become reduced to a geo-referenced point in a scientific figure that is part of a scientific story about something else, for example about weed control if the scientists was a weed ecologist (see Figure 2).

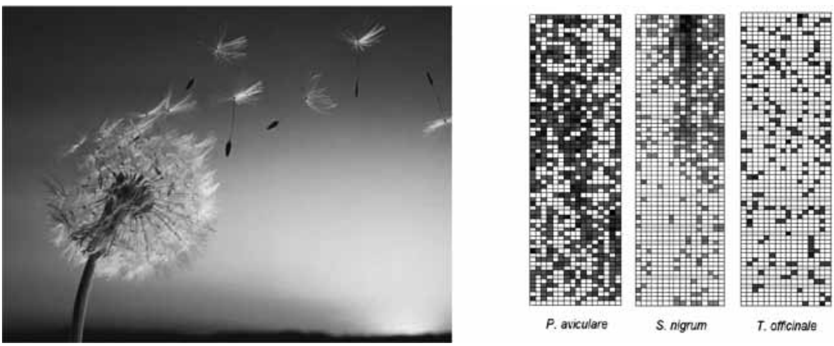

Figure 2. Different representations of the dandelion (Source of the right image: Heijting, 2007:16).

Of course, it is inevitable and to some extent necessary that scientists reduce reality in order to investigate specific questions. But it is important to acknowledge that somehow the scientific result constitutes a partial and selective representation of reality. I think Esther Brouwers's explanation is important, but there are other aspects that are relevant as well.

Making and shaping through knowledge and technology

Knowledge is not only used to describe, understand and interpret the world, but it also enables people to achieve social ends and values. This is expressed in words like 'know how' (Jansen & Vellema, 2011:171). If we have contextually valid knowledge, it may give us power to intervene and realize goals. We can, for example, incorporate knowledge in technical devices and practices that enable us to get rid of weeds in a more effective way.

In line with this, Paul Richards has defined technology as the human capacity and power to make, i.e. the capacity to achieve social and material ends in the process of using the technology (Richards, 2009; Jansen & Vellema, 2011). Thus, the use of knowledge and technology tends to go along with the realization of changes in the bio-material world, and – importantly- simultaneously with changes in the social world. In the field of Science, Technology and Society studies, a widely used phrase in this context is that technology and society mutually shape each other (Bijker & Law, 1992; Boczkowski, 2004). In the context of our University, we should perhaps better speak of the mutual shaping of technology, society and nature. In any case, there are numerous examples of such mutual shaping:

Technology-use and labour organisation – As the pictures in Figure 3 demonstrate, the use of mechanisation in agriculture has had significant consequences for labour relationships in the countryside; with mechanisation farmers did no longer have to employ labourers or work together. But one cannot usefully look at this as a one

Figure 3. Technology-use and labour organisation.

directional influence, since the relation may at the same time have been the other way around: changes in labour availability or tension between farmers and farm-labourers may have encouraged mechanisation .

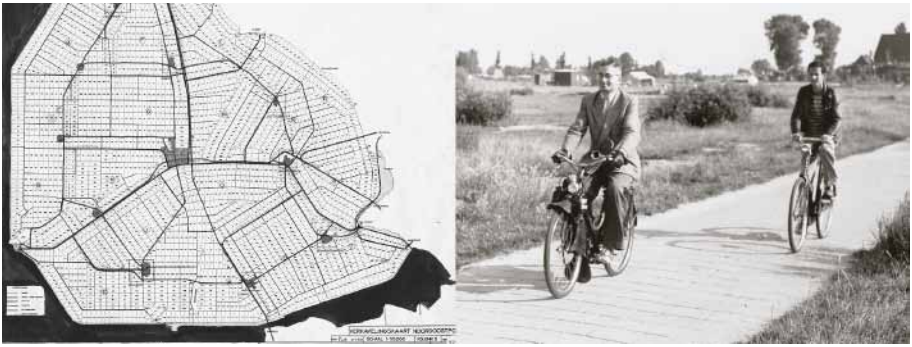

Figure 4. New transport technology goes along with changes in spatial and social organisation.

New transport technology and changes in spatial and social organisation – Increasing mobility by means of bicycles and also the Moped allowed for new ways of organizing polders (see Figure 4). In the polder design of the Noordoostpolder , farm labourers were destined to live together with each other in larger villages instead of on or very near the farms. This spatial re-organization also occurred elsewhere, and clearly meant a significant change in social relationships and interaction patterns in rural areas. Not something, by the way, that the designers of the Moped are likely to have intended or foreseen!

New communication technology-in-use may alter relationships – The emergence of the Internet (initially an infrastructure to improve coordination among the military) has been used in ways that drastically affect a range of relationships. At work, e-mail

Figure 5. New communication technology-in-use may alter relationships.

systems seem to make it easier to get in touch with the higher-ups, and thus affect organizational hierarchies. In addition, they have also allowed many people to make work-related communication an almost 24/7 affair.

And in Kenya, for example, the widespread use of mobile phones has made it possible for phone companies to compete with the banking system by allowing people to exchange phone credit rather than pay through a bank account. Similarly, the power balance between farmers and traders has changed due to increased transparency about prices in the market (Muto & Yamano, 2009). And computer based measurement and administration systems in dairy cooperatives seem to have helped to improve trust among farmers and the dairy cooperatives, as farmers can follow from their day-to-day printed receipts what the balance is between milk delivered and inputs they have bought through a check-off credit system that is integrated in the software package (Kilelu et al, 2013).

All these examples clearly demonstrate how the use of technology coincides with significant changes in social relationships!

Technology-use as performance

Another relevant conclusion to be drawn from the above examples is drawn is that outcomes realized are not necessarily deliberate or the same as those for which a technology was originally intended. In connection with this, Paul Richards has emphasized that one cannot pre-assume what objectives are being pursued in a specific setting, and that it is important to study 'technology-in use' to actually discover these (Jansen & Vellema, 2011). For example, one cannot simply assume that people who are managing cattle in Northern Ghana are aiming to produce meat, since for them cattle may primarily be a way of storing capital. Or closer to home: it would be wrong to assume that people buying nice cars aim simply to drive comfortably from A to B, since they may actually be more concerned with managing their social status vis-a-vis their neighbours.

In this perspective we can look at technology-use as a *performance* (Richards, 1989; Crane et al., 2011), in several meanings of the word:

(a) a performance, in the sense of goal-oriented-ness: through the use of knowledge and technology people usually aspire to achieve a variety of (hidden or explicit) outcomes;
(b) a performance, in the sense of an unfolding play or drama where there are different actors with different intentionalities interacting with each other and with their bio-material environment, thus shaping outcomes;

(c) a performance, in the sense that there are audiences who may be looking at the drama from a certain distance, and who may have their own altogether different interpretation of what is going on and of what is being performed, and who integrate that sense-making in their own performances. For example, the audience of relatively distant scientists, who may selectively look at the Northern Ghana cattle scenes from the perspective of the energy efficiency and CO_2 emissions, as part of a discussion about sustainable intensification.

Concluding on why knowledge and technology are so often contested

The above examples and reflections demonstrate that the availability and use of knowledge and technology is intertwined with efforts to achieve social ends and to re-organise social relationships. Thus, it should not surprise us that societal concerns regarding new technology often involve much more than concern with the bio-material implications of technology-use. There often is concern about the human values and the relational aspects involved. Such concerns can be about: (a) the social ends that are (assumedly) pursued, respectively those that are ignored; (b) the changes in social relationships that (are expected to) occur; and/or the (c) the real or perceived intended and unintended societal consequences that may arise from the use of knowledge and technology.

If we look, for example, at discussions about the use of genetically modified organisms (see also Jansen & Gupta, 2009), part of the debate is indeed on bio-material uncertainties and risks, such as the consequences for ecology, biodiversity and toxicity in the environment. But as the below pictures show (see Figure 6), a fair

Figure 6. Two pictures expressing relational concerns regarding the use of genetically modified organisms[1].

[1] HR 193 is the US Seed Availability and Competition Act that was discussed in the American House of Representatives in January 2013. It would require persons who save seed from crops they have grown with patented seeds to register with the Secretary of Agriculture and pay fees.

amount of societal criticism arises from concern on how societal relationships may change. These include concern about how changes in the ownership of life may result in shifting power balances in seed systems and reduced autonomy of farmers in breeding. Similarly, opponents fear that resource poor farmers may be excluded from reaping benefits, while Western seed companies may become rich through the exploitation of genes that have been taken freely from developing countries.

In the societal debate on genetically modified organisms, the bio-material and social dimensions become intertwined and almost inseparable. Those who are mainly concerned with the social consequences, for example, are still likely to strategically emphasize the bio-material risks as well if they expect that doing so will help to mobilize public opinion and political support for their viewpoints. In any case, it is clear that debates about technology are unlikely to be settled with technical arguments and discussions alone.

Another type of performance: communication
The two cartoon and poster shown in Figure 6, and the insight that people selectively use arguments to pursue certain social outcomes and interests, illustrate that – like technology-use – communication is a form of goal-oriented performance as well (Goffman, 1959). The images illustrate that the often made separation between what people *say* and what they *do* is in many ways false, as language philosopher J.L. Austin already assessed in his famous book "How to do things with words" (1962). When people *say* something, they simultaneously *do* something. They persuade, aim to convince, they accuse, promise, make war or peace. Thus, by means of language and other symbols people do not just aim to exchange meanings. People use them to pursue societal goals, and try to influence or reproduce interpersonal or societal relationships. And again – as with technology – the ends may be pre-planned, or they emerge in the everyday communicative performance, and are being interpreted differently by different parties.

Thus, words and pictures – or more broadly discourses[2] – are in a sense symbolic technologies, technologies of meaning making. This is a way of looking at communication that is certainly not dominant in the communication sciences, but in our section we are quite used to it (Te Molder & Potter, 2005; Lamerichs & Te Molder, 2009; Aarts et al., 2011; Van Bommel, 2008).

[2] Discourse can be defined as "a group of statements which provide a language for talking about - a way of representing knowledge about - a particular topic at a particular historical moment" (Foucault cited by Hall, 1997: 44).

The two pictures also demonstrate that these two types of performance (technology-use and communication) can be interrelated in several ways; in these cases we see how the one is used to undermine the other, but of course we also see situations where communication is used to advocate and support technology-use.

Innovation and the interweaving of the bio-material, the social and the symbolic

What does this all mean for the understanding of innovation? Many people still associate the term 'innovation' mainly with technical inventions and their integration in bio-material artefacts such as seeds, machines and associated technical operation practices.

However, the observed interdependencies between technology and society imply that we need to broaden the concept of innovation. Meaningful innovations inherently involve changes in modes of thinking and social organisation, including changes in the formal and informal rules and arrangements that orient the way humans act and interact (i.e. institutional change, see North, 1990). Building on Smits (2000) we can conceptualise innovations as a (re-)configuration of 'hardware' (the bio-material dimension: e.g. technical devices, physical practices, bodily skills), 'orgware' (the social dimension: relationships, institutions[3], organisational forms) and 'software' (the symbolic dimension: knowledge, meanings, visions, discourses) (adapted from Smits, 2000).

One can even go further, and say that effective or successful innovation (in support of certain goals and values; we are clearly not dealing with a neutral phenomenon) *requires* the emergence of a conducive coupling and balance between new 'hardware', 'software', and 'orgware' in societal networks of interaction. Hereby, new 'orgware' can be seen as the changes in, for example, policy, market organisation, legal frameworks, service provision and incentive systems that are often necessary to enable people to make use of new ideas and technical opportunities. I will come back to the issue of how the emergence of coherence and conducive coupling may come about and be supported. First, I would like to point out that this way of looking at innovation has proven to be extremely useful for explaining ex-post why technology do or do not become effectively used in society. Some examples are provided below.

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[3] Drawing freely upon economic and sociological perspectives on institutions (North, 1990; Scott, 1995) Elzen et al. have in this context distinguished between economic, normative and interpretative institutions (Elzen et al., 2012:5-6).

Understanding why technologies do not become innovations that work – As part of his PhD research in the Convergence of Sciences programme, Samuel Adjeih-Nsiah was aiming to introduce new crop rotation systems to combat soil fertility decline in Wenchi, Ghana. This rotation included the woody legume Pigeon Pea (Cajanus Cajan) that takes considerable time to grow and which has nitrogen fixing capacities, and thus potential to boost soil fertility for the next crop. He found that 40% of the land in the area was rented by migrants through short term rental or share-cropping arrangements that dis-encouraged them from using these kinds of crops (Adjeih-Nsiah et al., 2004). Samuel started to experiment with new longer term land-tenure contracts that would expand the time-horizon and allow migrants to invest in soil-fertility improvement. The results were disappointing. The specific customary land-tenure rules in Wenchi and the sub-optimal functioning of litigation systems made it difficult to uphold the contracts (Adjeih-Nsiah et al., 2008). In addition to this institutional barrier, the migrants in the end did not care all that much about soil fertility in the first place, and rather invested in building houses in their place of origin (Adjeih-Nsiah et al., 2007).

In this case there was clearly no alignment between the hardware proposed (pigeon pea), the orgware available (land-tenure systems) and the key players' software (the migrants ambitions and lack of a shared vision about the future).

Understanding why technologies do become innovations that work – The pictures in Figure 7 show the same technology being used in Germany and in the Netherlands. In both countries the use of grid connected solar systems on houses was made possible by national and European legislation that stipulated that all citizens are in principle allowed to deliver energy to the grid. Without that legislation – an institutional innovation – it is doubtful whether this technology would have taken off.

Figure 7. The uptake of solar systems in Germany (left) and in the Netherlands (right).

In Germany, the enthusiasm of citizens is far greater than in the Netherlands due to additional 'orgware' components such as conducive subsidies and pricing arrangements for sustainable energy production.

Understanding why accessible and effective technologies may not be promoted – PhD graduate Peter Gildemacher has been working on improving seed potato quality in Africa for a long time. Until quite recently, most efforts to in the formal research and extension systems went into developing pathogen-free-seed potatoes to be produced by specialized breeders, and sold on the market. This kind of research was popular among donors and private sector parties, as well as among scientists, because of all sorts of high-tech work that could be done with the help of genetic information (Gildemacher et al., 2012). In practice, however, few farmers could actually afford and access high-quality seed potatoes. In 2005, specialized seed potato growers managed to provide only a small percentage of farmers in East Africa with high quality seed potatoes (e.g. 2% in Kenya and 10% in Uganda) (Gildemacher et al., 2009; see for a broader discussion Almekinders & Louwaars, 2002).

At the edges of the formal system, Peter experimented with the re-introduction of on-farm positive selection of seed materials, an old forgotten technology that was no longer promoted since it was regarded as technically sub-optimal. The idea is simple: before the green leaves of the potato plant wilt and die, one marks the most healthy looking plants with a stick, and later harvest these as seed-potatoes for next year. Peter demonstrated that this was a very feasible and economically viable technology that considerably improved seed quality and yield, even though it did not completely eradicate disease (Gildemacher et al., 2012).

Here we see how incentive systems ('orgware') in the market and in science lead to the ignoring of options that are attractive to farmers, and an emphasis on high-tech problem-solving strategies that are considered more interesting in the scientific community.

Understanding why technologies are used, even though science questions their efficacy – The insight that innovation arises from a coupling between the bio-material, the social and the symbolic also helps us to understand why some technologies spread even though science questions their efficacy. Two such cases are discussed in "Contested Agronomy" (Sumberg & Thompson, 2012). The first is Conservation Agriculture, which is being promoted as 'farming God's way' (Andersson & Giller, 2012). The second is the System of Rice Intensification (SRI) (Shambu Prasad et al., 2012) of which several people in our group are studying the use and spread in India (Maat & Glover, 2012; Glover, 2011a, 2011b; Basu & Leeuwis, 2012). The System of Rice

Intensification is a set of practices that some associate with spectacular increases in productivity and efficiency, while prominent scientists argue that this cannot be true, resulting in what has been called a scientific 'Rice War' (Shambu Prasad et al., 2012). Research in India suggests that SRI as an idea and practice is spreading rapidly because proponents have managed to build a diverse and multi-level support coalition, that has become powerful and well-resourced, and which invests considerably in grass-roots learning, media presence and the building of a shared identity and sense of community (Shambu Prasad, 2006; Basu & Leeuwis, 2012).

Phrased differently, the contested 'hardware' is spreading on the wave of a common belief systems ('software') and 'orgware' in the form of some kind of socio-political movement.

Understanding why technologies continue to be used even though they are no longer seen as optimal – Another regularly observed phenomenon is that some technologies, such as intensive poultry systems and the QWERTY keyboard, continue to be used even though many agree they are far from ideal. Alternatives exist, but because everyone has become so used to cheap meat and typing the QWERTY way, that it is almost impossible to get rid of them. Over time, these technologies became so institutionalized and ingrained that it becomes hard to break out of the path paved by previous decisions, causing a lock-in situation (David, 1985; Arthur, 1989).

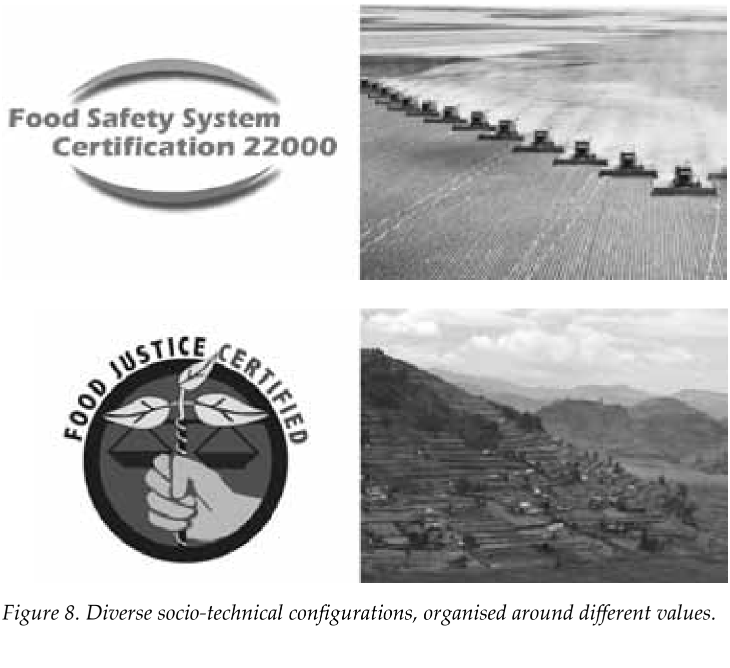

Figure 8. Diverse socio-technical configurations, organised around different values.

Understanding why diverse socio-technical configurations and orders co-exist – Looking at the interweaving of bio-material, social and symbolic dimensions and performances, also helps us to understand why eventually we see so much diversity in society. For example, as shown in Figure 8, we can observe value chains with different histories and types of players, organized around different values (as expressed for example in standards and certification schemes), operating in different ecological environments, using different technologies and modes of marketing, and with distinct patterns of interdependence and power configurations (see also Van der Ploeg, 2008).

Figure 9. Coupling through different modes of ordering.

In essence, these different value chains represent different patterns of interweaving and coupling the bio-material and social , resulting from different modes of ordering or coupling mechanism. Figure 9 captures five phenomena that are known to influence human practice, and which thereby shape, guide and order the interaction between these two worlds:

(1) *institutions* – there exist many formal and informal rules and arrangements that shape the way humans interact with the bio-material. Legal rules (normative institutions) often play a role in arranging access to resources such as water and land. And agricultural production strategies and practices are typically influenced by value systems and associated standards and certification schemes, and by the way regional and international markets are organised by means of, for example, trade agreements, import levies and rules for economic competition (economic institutions).

(2) *intentionality, agency and power* – human aspirations and their capacity to act (i.e. human agency, see Long, 1989) and realize goals in the interaction with the environment, clearly play an ordering role at the interface between the social and the bio-material (Crane et al., 2011). Whether people want to maximise short-term profit, or long-term objectives such as ecological sustainability can clearly influence the way they engage with the bio-material world.

(3) *technology* – as we have discussed earlier, technology is closely linked to the realization of human aspirations, and can be seen as a mechanism through which we interact with the bio-material environment (and with other humans). As we have seen, the kind of technology used can have meaningful intended and unintended consequences in the bio-material as well as in the social world.

(4) *knowledge and interpretation* – human interaction with the bio-material world is guided in many ways by what we know and have come to believe about it, resulting in expectations about what will happen when we engage with the bio-material environment in specific ways. Farming, for example, can be seen as a set of practices that is guided and underpinned by different forms and sources of knowledge, as informed by centuries of experiential feedback and insights from modern science (Van der Ploeg, 1990). Farmers may or may not alter their farming systems depending on their beliefs and expectations regarding climate change, which are in turn likely to be influenced by what they hear in the media and from friends and colleagues.

(5) *direct physical experience and skill* – interaction with the bio-material environment is also guided by skills and experiences that are more physical in nature, and that may be hard to explicate and/or transfer to others (Scott, 1998). Typically, agriculture requires considerable bodily skill, regardless of whether operations are carried out with 'simple' tools (like a hoe, or an ox-plough) or with higher degrees of mechanisation. The available skills can considerably influence the outcomes of whatever is being practiced.

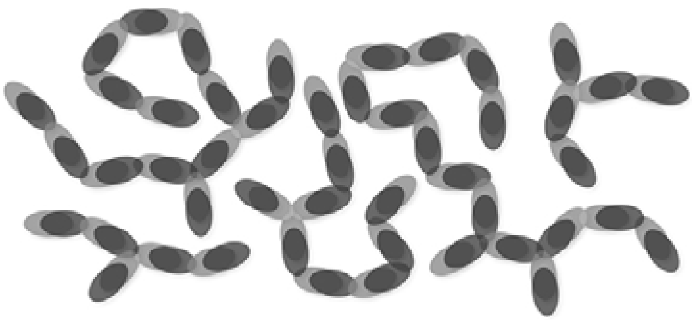

Figure 10. Coupling and (re)ordering in web of relationships.

When we consider that -for example in an agricultural value chain- there exist numerous activity domains (from production to consumption, and everything in between) that each include social and bio-material components, and that all practices are embedded in wider networks of relationships, each with bio-material and social dimensions and the associated coupling mechanisms, then it becomes clear that we are dealing highly complex web of interactions (see Figure 10). In these interactions, the social and the bio-material are intertwined to such an extent that these categories are only separable analytically. A seed variety, for example, might seem a bio-material phenomenon, but one could equally argue that it is the product of centuries of human usage, breeding and the application of human selection criteria (Almekinders, 2011). And hence something very social after all. And what seems initially social (e.g. friendship networks), appears to involve many bio-material artefacts (e.g. smartphones and other digital technology).

In the end, such complex webs and chains of interaction and practice result in societal patterns and outcomes (positive and negative) that are at least partially, and perhaps even mostly, un-intended[4]. As Sherwood et al. (2013) have signalled, nobody is *planning* for obesity, risk or poverty to emerge, even though it may be a logical outcome of how the system has become organized. At the same time, we need to acknowledge that even though there may not be an ex-ante conspiracy to produce undesirable effects, systems tend to be actively reproduced, and are difficult to change. This because negative outcomes occur at levels and domains that people do not oversee, and because there are always ingrained interests that powerful stakeholders chose to defend. For example, the recent initiative of the New York mayor to ban king-size sugary soft-drinks from the city's bars and restaurants was successfully attacked by the soft-drink industry.

So what about 'Science for impact'? How to capitalise on the 're-ordering' potential of knowledge and technology?

As we have seen, knowledge and technology are key elements in the coupling between social and bio-material dynamics, and tend to become contextually integrated in existing orders and configurations with more and less desirable consequences. This implies simultaneously that knowledge production (including scientific knowledge production) can potentially contribute as well to the *re-ordering* of socio-technical configurations.

But how does that work? And how can applied research organisations that have 'science for (societal) impact' in their mission statement optimally contribute to processes of 're-ordering'? This remains a relevant question, even when recognizing from the outset that science and research are certainly not the only or main contributors to change. This question is also highly pertinent for the international agricultural research organizations (members of the Consultative Group of

[4] Such outcomes may e.g. include: poverty and wealth; inclusion and exclusion; obesity and hunger; climate change or stability; scarcity and abundance; autonomy and dependence; safety and risk.

International Agricultural Research), which have recently been re-organized to deliver 'development impact'.
While striving for impact and relevance are laudable ideals, they come with a lot of difficult questions. What impact? For whom? Who decides about goals and trade-offs, for example between private and public values? Why and when is it legitimate for scientists to strive for certain impacts? How can scientists and research funders ensure that issues and impacts relevant to non-commercial interests and parties with limited resources are being addressed seriously?

Similarly, we may need to ask whether our research culture is conducive to our stated ambition. Striving for impact means contributing to the 'design' of the future, which implies in turn *synthesising* and *integrating* different understandings and building blocks (Tittonell, 2013). Traditionally, science and research is much stronger at *analysing* and *dissecting* what has occurred in the past (Remmers, 1998). Similarly, many scientists feel more at ease with a the self-acclaimed role of the outside observer, rather than that of someone who observes in the context of participating in action and intervention.

Before continuing the discussion about how research may contribute to change, it is relevant to ask what we know about how re-ordering of socio-technical configurations occurs. How does change happen in complex settings? In answering this question, my reference point are the types of significant re-configuration that one might want to see in order to address important challenges in the world, such as environmental degradation, disease and poverty.

How does change happen? How does 're-ordering' occur?

We have already touched on some relevant insights about this topic. Let me re-iterate some and add a few others.
First, it is important to acknowledge that meaningful change happens in networks of interdependent actors, who cannot change if others do not simultaneously change. Innovation depends on different stakeholders (e.g. parties in a value chain) adopting different practices in a more or less concerted manner – based on some kind coordination, agreement and mutual expectation. This implies that adoption of innovations is often not an individual affair, as is suggested by regularly used models of innovation and behaviour change (Rogers, 1995; Ajzen & Madden, 1986) in for example the health and agricultural sectors. As already hinted at, complex interdependencies and regularised interaction patterns in networks tend to constrain the space for meaningful innovation, not least since a number of actors in the network are likely to have a vested interest in maintaining the existing situation. At the same time, we need to acknowledge that the world changes continuously (and

quite radically at times), despite structural constraints and despite the experience that deliberately designed changes are not easily achieved and implemented. This brings me to a second insight, which is that in complex systems, new orders emerge usually without central steering and control (Van Woerkum et al., 2011; Leeuwis & Aarts, 2011). Instead, processes of 'self-organisation' (Nicolis, 1989) plays an important role in bringing about patterns of change. The term 'self-organisation' does not mean that change happens automatically and without human intentionality, but rather that it emerges as the unintended outcome of numerous intentional actions which interact and interfere with each other in complex ways (Sharpf, 1978; Castells, 2004; Van Woerkum et al., 2011).

A third insight, is that at any given moment there are different socio-technical configurations that 'compete' with each other and with the dominant system in an ever changing selection environment (Geels, 2002). For example, there exist several support networks and coalitions (called technological niches) around alternative transport technologies (e.g. electric cars, hybrid cars, bio-fuel cars or hydrogen cars) that compete with each other and with the fossil fuel car in a dynamic context. As we all know, it is not very easy to replace the fossil fuel car, essentially because it is already so well developed and supported by existing lobbies and infrastructures (with filling stations everywhere), our culture of car driving, and the relatively low price of high-quality combustion engines.

However, over time temporary or structural changes may occur in the selection environment – for example changes in energy prices, CO_2 taxation, demand for transport, the use of ICT to replace transport and/or in public opinion and actively exerted socio-political pressure. Such changes can help to shift power balances and feelings of urgency, and create windows of opportunity for change. Eventually, the 'best fitting' configuration becomes dominant in a given time and space context (Bijker et al., 1987; Rotmans et al., 2001), whereas other configurations remain marginal or become 'extinct' altogether.

A fourth insight is that such 'fitting' does not just involve adaptation to prevailing contextual conditions, but also the active influencing, by-passing or re-design of pre-existing conditions and frameworks, or even the 'overthrowing' of previously dominant 'socio-technical regimes' (Geels and Schot, 2007). Hence, innovation is in many ways a social struggle, whereby the success of initiatives for change depends on in part on the relative strength of the support network or coalition that proponents of particular technical and socio-institutional solutions manage to forge. In the sphere of transport, for example, we see that a successful lobby for altering the road tax system (an aspect of the socio-technical regime) in favour of environmentally friendly cars has boosted the sales of hybrid cards. Another key process in the competition for survival is that initiatives learn effectively from their experiences and the feedback from the bio-material and social environment, so that a mature balance and coupling arises between 'hardware', 'orgware' and 'software' components (Geels, 2002; Leeuwis, 2004; Smits and Kuhlmann, 2004; Hommels et al, 2007; Van Mierlo, 2012). Such learning and coalition formation does not simply occur automatically, and frequently requires active strategy, facilitation and deliberate efforts to stimulate critical reflection.

Finally, it is important to recall our argument that the separation between what people say and what they do is problematic. It is through communication that proponents of alternative technical and institutional futures strategically influence others, and forge what Hajer and Laws (2006) have called 'discourse coalitions '. Thus, meaningful change is dependent on changes in discourses, representations and storylines that are mobilised by interacting social actors. Such communicative devices play a significant role in the continuous ordering and re-ordering of the world, and in the 'preparation' and enactment of socio-technical change (Giddens, 1984; Hajer and Laws, 2006; Leeuwis & Aarts, 2011; Van Herzele & Aarts, 2013). In other words, change is both reflected in and produced by what Ford (1999) has called 'shifting conversations' in society. Nowadays, social media can play a significant role in this.

A complex systems perspective on innovation

Altogether, these insights reflect a complex systems perspective on innovation, whereby innovation in coupled natural and social systems can be understood as a shift from a previously dominant attractor to a new attractor that used to be latent, but that has gained strength over time (see Figure 11). A dominant attractor can be seen as "a state or a reliable pattern of changes (e.g. periodic oscillations) toward which a dynamical system evolves over time and to which a system returns after it has changed" (Coleman et al, 2007:5). Components of attractors (e.g. existing institutions and socio-technical regimes) recursively guide the self-organisation of the system. Innovation may be hindered by forces of the dominant attractor system, such as established mind-sets, vested interests, and existing codes of practice and conducts (Morgan, 1998), all produced and reproduced through dominant discourses, and leading to a high degree of resilience. According to Scheffer (2010), resilience includes a system's ability to cope with disturbance and re-organize itself towards original functions, structure, identity and feedbacks. However, a dynamic system does never return entirely to its original state. Not only the dominant attractor itself will slightly change as a result of the very effort to change it, but also the wider context is subject to continuous change whereby coinciding developments may reinforce latent attractors (Aarts et al., 2012). In this way, systems may gradually

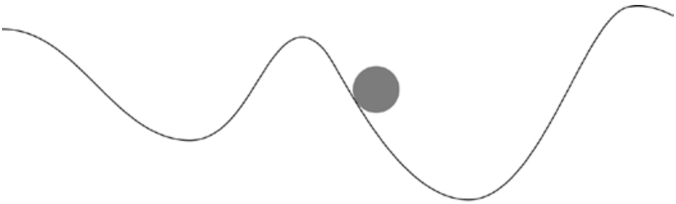

Figure 11. A dynamical system with two attractors of which 'fossil fuels' is currently strongest and dominant, while 'renewable energy' is weakest and still latent (Leeuwis & Aarts, 2011).

come closer to an 'edge-of-chaos situation' in which small changes at a critical moment can trigger major transforming effects (Morgan, 1998). Thus, working towards innovation can be equalled to changing the attractor landscape of the system (see Figure 11), e.g. by adding or strengthening latent attractors in combination with efforts to weaken currently dominant attractors. Phrased differently: stimulating innovation implies that one must focus the attention on changing 'the *potential* for change to happen', rather on than on working directly towards a clearly defined desirable system state.

Embedding research as a mechanism to adapt and enlarge the space for change

So what does this perspective on change and innovation imply for research organisations who wish to have societal impact? For example, international agricultural research organisations or applied research institutes in the sphere of public health.

It is clear from the above that innovation and change are negotiated in and between societal networks. The re-ordering of the world happens in society, and is unlikely to be steered by science. In order to have impact, science and research must somehow connect with the on-going dynamic, plug-in to the everyday conversations among citizens and in policy circles, and through this route enter societal decision-making. This may happen through various routes, including through classical dissemination strategies at the end of an otherwise relatively isolated scientific pipeline. However, we know already for a long time that such a linear strategy does often not result in well-adapted solutions (Kline & Rosenberg, 1986; Röling, 1988; Rip, 1995)

The potential of science-in-the-making

A key lesson that we learned in a variety of interdisciplinary programs is that in order to enter the conversations in society, science does not have to be 'ready' in the sense that it has resulted in a finished analyses, design or publication.

PhD graduate Jessica Milgroom, for example, was studying the livelihoods of people who were going to be resettled from Limpopo National Park in Mozambique, to an area outside the park. This resettlement was deemed necessary in view of the increased human-wildlife conflict that occurred after authorities had removed the fences between Limpopo National park and the neighbouring Kruger Park. Her experience and thesis demonstrates (among many other things) that the very fact that she was interviewing people and measuring their access to land and resources, influenced the dynamics of the resettlement process (Milgroom et al., 2011; Milgroom, 2012). People became more aware and knowledgeable about their resources, and the almost raw data that Jessica collected already became part of the negotiations about compensation between Park authorities and villagers. This was literally years before the data were properly analysed and got published in a journal article, as part of a scientific argument which was in the end quite different from the argument the villagers wanted to make at the time.

Also in Mozambique, PhD graduate Marc Schut synthesized data collected on biofuel initiatives in a map that showed the discrepancy between where policy documents said the benefits of bio-fuel production would happen (in poor isolated areas) and where they were actually taking place (Schut et al., 2010a; Schut, 2012). Again, this simple map alone influenced the societal debate, way before it became part of a finished scientific paper.

More in general, we see that societal stakeholders integrate data and insights derived from finished or unfinished research into their communicative performances, and use them to pursue their own social ends, or even as symbolic 'weapons' in their struggles. This may well be in ways that researchers find questionable or even abusive, but whether we like it or not, such processes reflect key mechanisms of how science results in impact. Hence, these are mechanisms we may need to better anticipate in our scientific work (Leeuwis, 2003; Giller et al., 2008).
In any case, the realization that research may influence society (i.e. have impact) while it is still in-the-making is significant, and once again calls into question the idea that one can usefully make a separation between a 'science phase' and an 'impact phase'. This maybe one pathway to having impact, and there are certainly examples of this happening, but the examples I gave demonstrate it is certainly not the only one.

Embedding science in the on-going dynamic

I would like to propose that in complex settings especially we need to more deliberately place science in the ongoing dynamic, rather than maintain the somewhat illusionary idea that scientists are or can be outside observers. This to ensure that research becomes a relatively rapid and effective mechanism for adaptation to ever changing circumstances, and simultaneously a mechanism to change conditions and alter 'the potential for change to happen'. That is: a mechanism for enlarging the (bio-material, social and symbolic) space for change. As signified by the current popularity among scientists of notions like Research for Development (R4D) platforms (Nederlof & Pyburn, 2012; Meridian Institute, 2013), Partnerships and Learning Alliances (Horton et al. 2009; Smits et al., 2007) there is increasing recognition that such embedding is important (see also Van Paassen et al., 2011). When operationalised well, such platforms can indeed help to ensure that relevant questions are addressed and that people are already waiting for data and results while the research is carried out, and before they are written down in a scientific article. But there are also many pitfalls. In actual practice such platforms and alliances may be affected by modes of research planning and funding mechanisms that make it difficult to turn research into a truly collaborative or demand-led endeavour (Klerkx & Leeuwis, 2008). Similarly, such platforms may be established mainly for diffusion purposes or become inflexible and artificial structures that remain somewhat disconnected from on-going initiatives and dynamics in society. To prevent this latter from happening, I would like to point to three key research strategies that may be especially relevant for both natural and social scientists in collaborative settings.

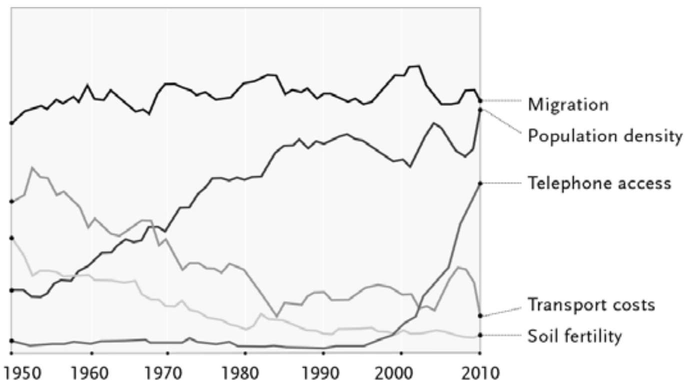

Figure 12. Fictitious overview of simultaneously occurring trends.

Characterising changing selection environments – A first type of collaborative research is more diagnostic in nature, and serves to find promising entry-points for further investigation, vision development and action. Such diagnosis can usefully involve a multi-disciplinary characterization of how selection environments are changing. Changes and happen in different spheres and at different levels. So this kind of endeavour requires insights from different disciplines and also from different stakeholders. In Figure 12 this is represented through a fictitious overview of simultaneously occurring trends . Basic purpose of such an exercise is to identify emerging tensions, constraints and windows of opportunity that set the agenda for further activity (see also Box 1 for a narrative example). Several scientific and facilitation tools exist to conduct such longer term analysis, including modelling, simple scenario analysis, but also life histories, filmed narratives and forms of future exploration (Sterk et al., 2011; Van Paassen et al., 2011; Witteveen & Lie, 2009; Lie & Mandler, 2009).

Box 1. Example of an emerging window of opportunity or latent attractor

In the beginning of the 21st century, for example, we witness a number of relatively independent developments: (1) rapid population growth in China; (2) increased presence of China in the African continent; (3) improved access to Internet in both China and Africa; and (4) the recent signing by China of WTO treaties. In view of these coinciding circumstances, it is not unthinkable that African smallholders might be able to gain access to the Chinese food market. Of course, it would require a network of people to see the opportunity, gain insight in the Chinese food preferences, introduce e.g. soybean production in Africa, find reliable business partners in China, organise transport and permits, etc. It may never happen, or it may happen in such a way that smallholders do not benefit. And the wider consequences of it happening are difficult to foresee: will it undermine local food security in Africa, or boast local economies and food production? But the least one can say is that the window of opportunity for accessing the Chinese market is probably enlarged when compared with the previous decades. In other words: the latent attractor that African farmers access the Chinese market is deepening.

Creating variation: engaging in societal experimentation with multiple socio-technical options – A second type of research is geared to creating more variation in society, building upon earlier diagnostic work. In order to be adaptive and create space, society needs to experiment in the field with multiple (combinations of) social and technical options, that may be located at different levels. Figure 13 represents an idea for such a field experiment, developed by Willem Takken and his group, that is currently piloted on Rusinga island in Lake Victoria, Kenya (Hiscox et al., 2012). The idea is to use of odour baited mosquito traps in order to eradicate malaria. The traps need some electricity to function, which is why this experiment also involves rural electrification through solar panels. To make the 'hardware' function, all sorts of 'orgware' issues need to incorporated as well, for example in the sphere of funding, maintenance and gaining support from authorities, the health sector and existing energy providers.

Research can easily link in to such collaborative field experiments. It can initiate them, generate and offer alternative designs, study questions and uncertainties that stakeholders have, monitor intended and un-intended consequences in different spheres, and make trade-offs transparent. And in the process of doing so help stakeholders to develop common understandings and insights that help them overcome their differences and strengthen the support coalition (if warranted).

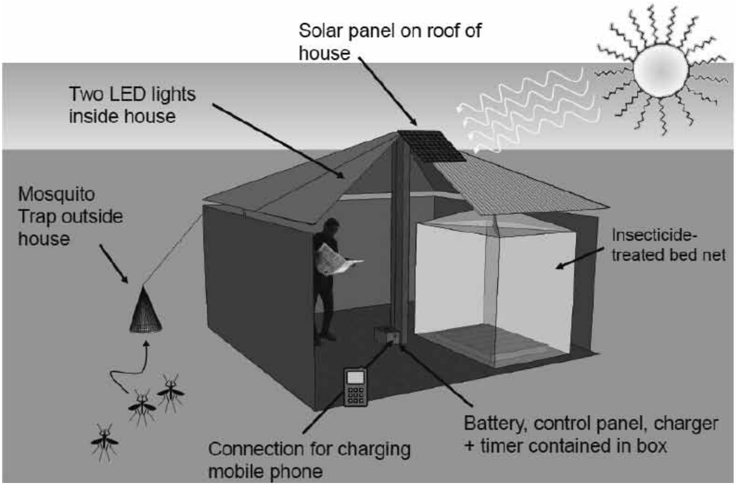

Figure 13. The Solarmal (Solar Malaria) design piloted in Rusinga.

Basic purpose of this kind of contextual field experiments is to enhance the learning capacity of society, and improve the chances of socio-technical innovations becoming well adapted to their dynamic environment (Klerkx et al., 2010), or help to decide in a timely fashion that initiatives are unlikely to succeed and should perhaps be discontinued.

An important thing to keep in mind here is that these kinds of experiments should not be massive interventions that create a totally artificial environment, because this defeats the purpose of enhancing adaptation and changing conditions in a sustainable manner (Hommels et al., 2007).

Studying existing diversity: understanding on-going space creation – In any context society is not waiting for science to come by and make its contribution. Change is already in-the-making, and we must realize that societal experiments are already taking place, even if they are not labelled as such. This is reflected in the fact that we always see a lot of diversity (Van der Ploeg, 1990), regardless of the societal domain. This already existing diversity can be a highly relevant resource in enhancing our adaptive capacity, especially because some networks of people are likely to have already discovered or created useful ways forward in addressing societal challenges (Marsh & Schroeder, 2002). In relatively homogeneous settings, some hospitals do manage to forge effective coordination between medical disciplines, and others do not. Some farmers or communities manage to have relatively moist soils in situations where others face draught. And some families manage to stay healthy in environments where others get sick. This existing diversity is arguably a resource that is under-utilised by science and policy in enhancing our adaptive capacity. Thus, as a third strategy, science and research can usefully identify and study existing diversity within seemingly homogeneous categories, and aim to understand what is special about cases that stand out positively. And subsequently underlying principles may be further tested, enriched and adapted into feasible social and technical options for others. Our group is currently conducting a research program in Ecuador to further explore this type of work, that in essence seeks to better ground the support of innovation and development trajectories in self-organisational processes (Sherwood et al., 2012).

The significance of new style innovation intermediaries in innovation systems

The embedding of research in on-going processes of change, and more in general the supporting of meaningful innovation is complex settings, is something that requires new kinds of professionalism and support. Catalysing and supporting change may usefully involve orchestrating new connections and coalitions between (networks of) actors and disciplines, mediation in situations of tension and conflict, and the facilitation of exchange, learning and vision building among diverse communities (Leeuwis, 2004; Hall, 2006; Fisher & Vogel, 2008; Szogs, 2008; Klerkx & Leeuwis, 2008b; Boon et al. 2008; Klerkx et al., 2009). Such roles may be performed by what Howells (2006) has labelled 'innovation intermediaries': "an organization or body that acts as an agent or broker in any aspect of the innovation process between two or more parties. Such intermediary activities include: helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator, or go-between, bodies or organizations that are already collaborating; and helping find advice, funding and support for the innovation outcomes of such collaborations." (Howells, 2006:720). Clearly, such innovation intermediaries perform far broader roles and operate in much wider networks than the classical 'extension agent' who was seen to provide 'knowledge transfer' and/or 'individual decision-support' – functions that also remain relevant of course (Van den Ban & Hawkins, 1996; Smits & Kuhlmann, 2004; Van Lente et al., 2003; Hekkert et al., 2007). In the context of the ambition to effectively embed research, a key intermediation task (that may be performed by researchers or process facilitators) is the eliciting of relevant questions for research, including those that are hidden in the interaction among stakeholders, and the uncertainties and doubts that they experience in relation to social and technical options. Turning such questions into a coherent interdisciplinary agenda for collaborative research is a key prerequisite for doing 'science for impact' (Klerkx et al., 2012), as one of the strategies to enhance the functioning of innovation systems (Hekkert et al., 2007). Eventually, the performance of a variety intermediary roles can – in combination with strategic championing activities (Shambu Prasad, 2006; Klerkx & Aarts, 2013) - contribute to the emergence of diverse and powerful discourse coalitions in support for new socio-technical configurations.

Beyond virtual reality: the significance of contextual research

Implicit to the kinds of research suggested above, is an emphasis on developing contextual understandings, which implies simultaneously an interdisciplinary understanding. A worry I have in relation to this, is that – despite all the interest in complexity – we still have many incentives for doing narrow disciplinary research in 'easy' research settings. Even in an integrative field such as agronomy, students may prefer to study phenomena only in controlled settings such as laboratories, computer models and experimental research facilities (see Box 2). And in the social sciences – for example in social psychology and regular communication science – quite a bit of research is done nowadays with mainly students as respondents. Similarly, we see that scientists often study processes from a narrow disciplinary perspective (e.g. focusing only on individual or collective dimensions of human behaviour, without looking at the linkages).

Box 2. Hesitations to do research in complex settings

I recently attended a seminar in which several plant science PhD students indicated that they were hesitant to conduct research on farm or even on-station , because of the problems it posed regarding making sense of multiple influences. Harro Maat too has pointed to the fact that the nature of scientific experimentation has changed and that a 'rather unproductive gap' has emerged between scientific and, in his case, farmer experiments (Maat, 2011).

Thus, we may produce 'virtual reality' research, even when the data are real. That is, research that over-simplifies reality and turns findings into the kind of catchy and positive scientific story that journals like, and seem to prefer over more nuanced, complicated or sobering arguments (see Stapel, 2012; Abma, 2013). In other words, science runs the risk of reducing reality to such an extent that it no longer leads to contextually valid knowledge (Van der Ploeg, 2003; Maat, 2011; Crane, 2010). This is paradoxical at a time when society demands that farming and other activities become more ecologically sustainable, as this ambition typically demands a holistic integration of contextual knowledge and understanding.

Contextual research does not immediately lead to generalizable results, but –besides offering understandings that are valid in real-life- it can lead to the identification of patterns across sites, and help us to generalize at the level of theory. Moreover, well embedded contextual research creates a partially shared context and space for scientists and citizens, which could somewhat reduce the risk that scientific findings and arguments are fitted in societal storylines in ways that we as researchers would find totally inappropriate.

Researching the dynamic coupling between the Bio-Material, the Social and the Symbolic

The research of the Knowledge, Technology and Innovation group will be embedded in a broader collaborative research programme of the section Communication, Philosophy and Technology: Centre for Integrative Development. Furthermore, our research contributes to several themes of the Wageningen School of Social Sciences. Finally, both streams in the KTI group have a strong tradition in collaborating with our natural science colleagues, and we will continue to cherish those relations.

In the preceding parts I have touched on various aspects of our research agenda already. In essence we study and aim to build theory about different aspects of the dynamic coupling between the Bio-Material, the Social and the Symbolic. Below I outline some relevant aspects and lines of questioning . Addressing these questions will lead to new fundamental insights in the communicative and socio-political dynamics of socio-technical innovation and transformation, which is the core mandate of the Knowledge, Technology and Innovation chair.

1. Anchoring: How and why do new connections emerge, and how are existing connections broken? How do new connections become durable?

We know that bio-material, social and symbolic are intricately intertwined, and that new configurations are needed to address pressing issues in the world. But strictly speaking we know little about the patterns through which new linkages around bio-material, social and symbolic novelties come about and about how old connections are broken. We have recently written about this using the analogy of an anchor, to characterise the initial instability that may occur in new relationships: anchors can dig in deeper and become solid links, but they may also slip and let go if forces are going in opposite directions (Loeber, 2003; Elzen et al, 2012). These kinds of questions can also be asked at the level of interdisciplinary collaboration in science.

2. Competition: How can we understand the success or failure of new configurations in the competition with others?

As indicated it is clear that different possible futures exist at any moment in time, and that both coincidence and competition between socio-technical configurations shape how things unfold. There is a lot of scope for developing a better understanding of the success or failure of new configurations in the competition with others. Such competition is likely to happen in various dimensions: the dimension of developing social and technical options that actually work in a specific setting; the dimension of societal discourses about such options; the dimension of networks and support coalitions; the dimension of financial gains and their distribution.

Developing an integrated understanding of how these dimensions of competition relate to each other is likely to generate new insights for different social science disciplines.

3. Public value creation: What are the consequences of alterative configurations for especially vulnerable people and public interests in different settings?

It remains highly relevant for a socially responsible University to uncover the intended and unintended consequences and impacts of the everyday-use of socio-technical innovations in different social as well as time and space settings. Such impacts need to be evaluated against normative standards in the sphere of ethics and social justice, including considerations related to equity, solidarity, dignity and democratic and human rights. Such research can provide feedback to societal actors and lead to the adaptation of socio-technical innovations. Moreover, comparative research across contexts can reveal conditions that affect whether or not particular technological and institutional designs contribute to achieving developmental objectives. In connection with this, we may gain understanding in the extent to which consequences and impacts for different categories of people (in different time and space settings) can be foreseen and anticipated, and in the kinds of methodologies can be used effectively for this purpose.

4. Innovation intermediation: What are the potential and limitations of classic and new communication and innovation intermediation strategies in influencing desirable coupling, change and adaptation?

In the past decade we have witnessed the emergence of new intermediary actors and intervention models (for example Research for Development Platforms and Business Hubs) in innovation systems. Current studies on these often look at their effects, but give little insight in their actual operation, the interactions that are orchestrated, the dilemma's that professionals face and the mechanisms through which outcomes come about. Studying the everyday practice and performance of these intermediaries and the enactment of new intervention strategies, can lead to highly original contributions to innovation studies; a field that is currently more oriented towards macro phenomena. In this research line, we will also seek to understand factors influencing synergy between new forms of intermediation and classical extension.

5. **Knowledge and re-ordering: What is the role of science, research and everyday expertise in re-ordering the relations between the Bio-material, the Social and the Symbolic? What financial and decision-making arrangements help to secure vulnerable interests?**

We have seen that different forms and sources of knowledge and understanding have a potential of contributing to societal re-ordering and innovation. However, given the competitive nature of change processes, confrontations between different representations of reality and truth are likely to occur as part of initiatives for change. In this context, it is relevant to develop a better understanding of how knowledge and perspectives become and remain dominant and institutionalised (e.g. in regulations, disciplines and policies) and how they may be 'unfrozen' again when conditions change. The influence of various financial, planning and decision-making procedures for setting research agendas is of special interest in this regard. More in general, we are interested in looking at the potential and limitations that different strategies for embedding research in society have for the re-ordering the relations between the Bio-material, the Social and the Symbolic.

Assessing the societal impact of embedded research: process histories of socio-technical change-in-the-making

The research agenda presented above will require innovation at the level of research methodology. Fortunately, we can make use of and re-combine a rich set of research strategies that are already available in the Knowledge, Technology and Innovation group and the wider section (see below). At the same time, especially the last point in the research agenda dovetails to a considerable extent with the understandable wish of applied research organisations (such as those united in the Consultative Group of International Agricultural Research) to assess the societal impact of embedded research in complex environments. In relation to this, it is relevant to note that the theoretical perspective presented here on technology-use, change and innovation deviates considerably from earlier perspectives on technology transfer and uptake, in which research impact was studied mainly in terms of technology 'adoption' (by end-users) and 'diffusion' (among a broader population of end-users) (see Rogers, 1995; Leeuwis & Aarts, 2011). Even today we see, for example in the realm of international agricultural research, that the societal impact of research still tends to be assessed on the basis of the mis-conception that innovation is mainly about the uptake of technology, and that the prime locus of adoption decisions is the individual. The complex systems perspective on innovation presented in this inaugural lecture implies that we need to re-think the value and meaning of old concepts, and complement them with other variables and indicators. Assessing new ways of embedding research with old concepts , variables and measurements is risky, as it would render invisible some key components of change and innovation, as well as less tangible but critically important intermediary indicators for change.

Overlooking such components and indicators may lead to flawed conclusions regarding the contribution (or the lack of it) of embedded research efforts to (the 'deepening' of latent attractors for) development. Therefore, the Knowledge, Technology and Innovation group could make a significant contribution to practice if it combined its academic research ambitions with the development a better conceptual and methodological apparatus for assessing the societal impact of research. Some ideas about the key variables and that could be included in such a framework are listed in Table 1.

Table 1. Characteristics of classical ways of assessing the societal impact of research (in international agricultural research), and additional angles proposed.

	Classical assessment focus	**Additional assessment focus**
Kind of change assessed	. change in 'hardware': technology-use	. change in 'orgware': institutional change . change in 'software': thinking, visions, agreement, discourse, learning from failures
In other words: 'Adoption and diffusion' of	. technology, technical practices	. rules, processes, ideas, discourses
Level at which change is assessed	. individual or household characteristics	. network characteristics: e.g. coalition formation
Practices considered	. specific practices by eventual beneficiaries	. multiple interdependent practices by various stakeholders
Objectives considered	. intended objectives of funding sources	. un-intended consequences and emergent objectives of stakeholders
Type of indicators	. outcome indicators	. process indicators
Impact from	. research products	. research process
Research design	. oriented to assessing attribution of change to research	. oriented to assessing contribution of research to change

In essence, the argument made above is that an assessment of whether research (or for that matter any other intervention) contributes to meaningful change in complex settings, requires an opening of the black box of change-in-the-making. In complex systems language: we need to uncover how 'latent attractors' are strengthened or weakened. Thus, we need to develop sensitive (Knorr-Cetina, 1981) and feasible research strategies that somehow capture relevant aspects of process history. As mentioned, the Knowledge, Technology and Innovation group is well positioned to develop such an alternative approach, since we have experience with a number of highly relevant building blocks (see Table 2) that are able to capture relevant angles proposed in Table 1.

Table 2. Candidate building blocks for making process histories of socio-technical change-in-the-making.

Methodological building blocks	**Captures**	**Examples of relevant work**
Technography: ethnography of technology-in-use	Making / Performance Distributed Cognition Construction of Rules	Vellema, 2005 Jansen & Vellema, 2011 Almekinders, 2011
Innovation Histories & Process Ethnography	Critical Events Learning	Klerkx et al., 2010 Schut et al., 2010b Kilelu et al., 2013 Leeuwis, 2004
Network Analysis	Changing Coalitions	Hermans et al., 2013
Reflexive Monitoring in Action	Process Indicators Learning Institutional Change	Van Mierlo et al., 2010a Van Mierlo et al., 2010b
Discourse Analysis	Shifting Conversations	Van Herzele & Aarts, 2013; Aarts et al., 2011
Causal Process Tracing & Realistic Evaluation	Mechanisms / Contribution	Nuijten, 2011 Ton et al., 2011 Vellema et al., 2013 Pawson & Tilley, 1997 George & Bennet, 2005

I see a lot of scope for combining these methodological approaches in such a way that they may be useful for science and practice.

A word of thanks

Esteemed Rector Magnificus, colleagues, students, ladies and gentlemen,

Merging two successful groups, each with their own history, culture and identity is an interesting and challenging process. I am not sure that separating two successful groups at the same time has been tried before, but I can tell you that that also poses several puzzles. Combine that with the building a new common umbrella – the section Communication, Philosophy and Technology: Centre for Integrative Development- and one can be sure that there is never a dull moment.

Martin, you have asked us to walk this route and live this scenario; I frame that at this point as indicative of a large amount of confidence that you have in the quality and resilience of our section and its staff. Thank you for that!

I would like to warmly thank the members of my new Knowledge, Technology and Innovation group, who are constructively building and shaping our new home, and looking for new opportunities. I am extremely grateful for your enthusiasm and commitment to doing good academic work, and for the cooperative atmosphere to which you have all contributed, each in your own specific way, as is needed in a good team. Similarly, I would like to express my gratitude to all PhD students in the section. You are an important source of inspiration and pleasure, and contribute enormously to maintaining a good academic and social climate.

A special word of thanks also to our support staff, Vera Mentzel, Annette Dijkstra, Mirjam Cevat, Sylvia Holvast, Inge Ruisch, Bea Prijn and education coordinator Mieke Muijres, for their assistance, care and courage to start collaborating in a new way. The fact that the new section as a whole is taking-off in such a positive spirit is an achievement to which all staff have contributed; I am very grateful for that! I am especially thankful for the leadership roles that Michiel Korthals, Noelle Aarts and Kees Jansen have played in this as members of the management team, and for the positive energy Sietze Vellema has provided as coordinator of our support staff. I am looking forward to further develop the section with all of you, and with our newly appointed professors Marcel Verweij and Peter Feindt.

In the recent past, I have had a lot of assistance from several people in the Social Sciences Group and the Wageningen School of Social Sciences in dealing with some unusual hurdles; I would like to especially than Dirk-Jan de Boer, Frans van der Goot, Ingrid Hijman, Lucia Teunissen, Eveline Vaane, Esther Roquas and last but not least Laan van Staalduinen. I have highly appreciated your support!

It is great to be able to work with young BSc and MSc students who are eager to learn almost every day! In this inaugural address I did not say much about our education systems, but a lot of what I said 10 years ago is still valid. I remain convinced that we can and should foster a better and more flexible academic climate, with less detailed programming of education.

Working in Wageningen is fascinating, especially since it offers ample opportunities to collaborate with natural scientists. I myself and my group have worked together with many people from quite a few different disciplines, and that has been very rewarding not only in terms of gaining interesting interdisciplinary insights, but also for making innovative contributions social sciences more narrowly. Thank you for your inspiration and support!

I continue to owe a lot to my predecessors, promotors and supervisors – Anne van den Ban, Niels Roling, Cees van Woerkum, Norman Long and Jan Douwe van der Ploeg – and I am proud to have the privilege of adding Paul Richards to those ranks. Paul, you have contributed enormously to building a strong group at the interface between natural and social sciences. It was never my plan to become your successor, but now that I somehow am, I will do my best to build on your academic legacy too.

I thank my parents for their never ending love and support, and Joost and Juul for being the best brother and sister that I could wish. I thank Luc and Olga for their friendship, and the warm home they help to create in Beek-Ubbergen.
Rosa and Rafaël, I am terribly proud of see you grow in every aspect of life, and extremely happy to be part of your journeys!

And then there is Noelle. You are the love of my life, my guardian angel, and a continuous source of new ideas and inspiration for me and others. Besides all that, you have contributed enormously to whatever success I have had in my work, often in largely invisible ways. Admittedly, in several dimensions, balance has been lacking in the past years. But change is in-the-making! Thank you for everything, and especially for sharing your life with me!

Ik heb gezegd.

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'Despite their obvious contribution to society, science and technology are often contested. Why? Because they are inherently connected with the reorganization of social relationships and value achievement. Thus, innovation arises from a re-configuration of 'hardware' (the bio-material), 'orgware' (the social) and 'software' (the symbolic). In complex settings, re-configurations emerge from interaction in networks, rather than by purposeful design. In order to help realize public values, research needs to become a mechanism for adaptation to ever changing conditions, and catalyze the enlargement of bio-material, social and symbolic space.'

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