## Agri-food innovation and impact

# Discussion paper series

The CSIRO & CGIAR Independent Science and Partnership Council (ISPC) Secretariat have developed a series of discussion papers to advance debate around agri-food innovation and impact.

The purpose of this series is to:

- provide an avenue to disseminate preliminary findings, ideas, reviews and think pieces based on work in progress, and
- generate discussion, comments and suggestion for improvement prior to formal publication.

The series is open to researchers and practitioners working on agri-food innovation and impact challenges.

For more information or copies of other discussion papers please contact:

Dr Andy Hall
CSIRO
Andrew.Hall@csiro.au

or

Dr Jeroen Dijkman
CGIAR ISPC Secretariat
Jeroen.Dijkman@fao.org

# Synopsis: Towards a framework for unlocking transformative agricultural innovation

Andy Hall[1], Jeroen Dijkman[2], Bruce Taylor[1], Liana Williams[1] and Jennifer Kelly[1]

## Context

The agriculture sector needs to do much better at innovation. Increased demand for food, plateauing productivity, changing patterns of competition and consumption, accelerating climate change, concerns over food safety, and the need to address these issues in a socially and environmentally sustainable manner, are just some of the reasons. These challenges are as relevant to Australia as they are to the world.

To improve agricultural innovation, the broad prescription is that research and technology needs to be better coupled with market and policy changes that allow ideas and solutions to be deployed. Australian and international agriculture sector players, however, continue to grapple with questions on how to implement this prescription. In particular, on how to arrive at a mode of innovation that matches the ambition of transforming the performance and sustainability of the sector, both now and in the challenging years ahead.

## Study purpose, framing, and approach

The purpose of this study was to develop a framework to better understand the relationship between different innovation configurations (partnerships, networks, and practices) and impact. Our starting assumption was that while configurations are contextually specific, broad patterns of practices and partnership associated with innovation and impact would emerge. Our logic was that these patterns could then form the basis of a framework to better explain how impact takes place, and point to tools and practices that increase the likelihood of innovation and impact.

The study approach was to undertake theory-informed process analysis of the manner in which innovation and impact processes unfold over time. The key analytical perspective used was that of innovation systems, an empirically based concept underpinned by systems and evolutionary economics theories that explains

[1] Commonwealth Scientific and Industrial Research Organisation (CSIRO)
[2] CGIAR Independent Science and Partnership Council (ISPC) secretariat

the innovation process as a networked and socially embedded phenomenon, driven by evolutionary learning and systemic change (see Box 1).

**Box 1: Innovation systems analytical framing**

The concept of National Systems of Innovation emerged out of the need in the late 20th century to explain patterns of economic growth where innovation, rather than Research and Development investments *per se*, was the key ingredient. The key insight was recognition of the economic significance of the ability of countries not just to generate technology and ideas, but most importantly the ability to use these ideas in economically and socially significant ways. Based on considerable empirical evidence and underpinned by systems theories and evolutionary economic perspectives, the innovation systems concept has emerged as a powerful tool for revealing the processes and capabilities associated with innovation. It is used extensively to frame national science, technology, innovation and industrial policies.

In the international agricultural research domain considerable work has been done on elaborating and applying the idea of agricultural innovation systems (see World Bank, 2006 and 2012, Robertson 2016). Here the concept has been used in sectoral and sub-sectoral systems analysis and often at project scale to frame practice. This has strayed from its original emphasis on national systems. Nevertheless the concept is now quite mature and points to a number of lines of enquiry for exploring the nature of the innovation and impact process that informed our case study analysis.

Conceptual development on understanding how agricultural innovation takes place is now quite mature and considerable work has been done on elaborating the idea of agricultural innovation systems. Key points from this perspective include the following:

- Innovation is not research or technology but often involves both.
- The critical feature of innovation is not novelty in the sense of invention, but novelty in the sense of putting ideas into use in new ways for economic and social gain.
- Innovation can involve technological change, institutional change, business model change and policy change and is usually a combination of these.
- Innovation emerges from dense networks of interaction and this often involves a two-way interface between knowledge creation and knowledge use by farmers or companies.
- Innovation is a multi-scale phenomena with, for example technological changes at the farmer level being co-dependent on accompanying changes in markets and policy regimes.
- Innovation rarely a linear predictable process of ideas -application-impact. Instead it involves complex pathways and chains of events with innovation

trajectories unfolding in un-predictable ways often over long time frames. This often involves feedback loops where ideas are refined and applications are adapted to be fit for purpose.

- Innovation capacity has multiple dimensions. (i) Skills in research, business practice and management. (ii) Routines and learnt behaviors of organization that help in creating interfaces with sources of ideas and partners. (iii) Links, networks, partnerships and alliances that connect players, allow ideas to flow and help in the co-construction of conditions to use those ideas. (iv) Policy regimes that encourage innovation through incentives, investment and regulation.
- The roles of the public and private sectors is neither mutually exclusive nor fixed. Instead the roles of players evolves during the innovation process, with configuration of players adapting to the contingencies of opportunities and challenges being addressed.
- Innovation creates winners and losers. As a result politics, power and competing agendas shape the pace and direction of innovation as dominant stakeholders jostle to capture new opportunities or to maintain the status quo where it is to their advantage.

Figure 1 illustrates the different analytical lenses that innovation systems' thinking bring to bear. The framing used to explore a series of case studies is presented in annex 1. Case studies used information collected from secondary sources, and interviews with key project staff where possible.

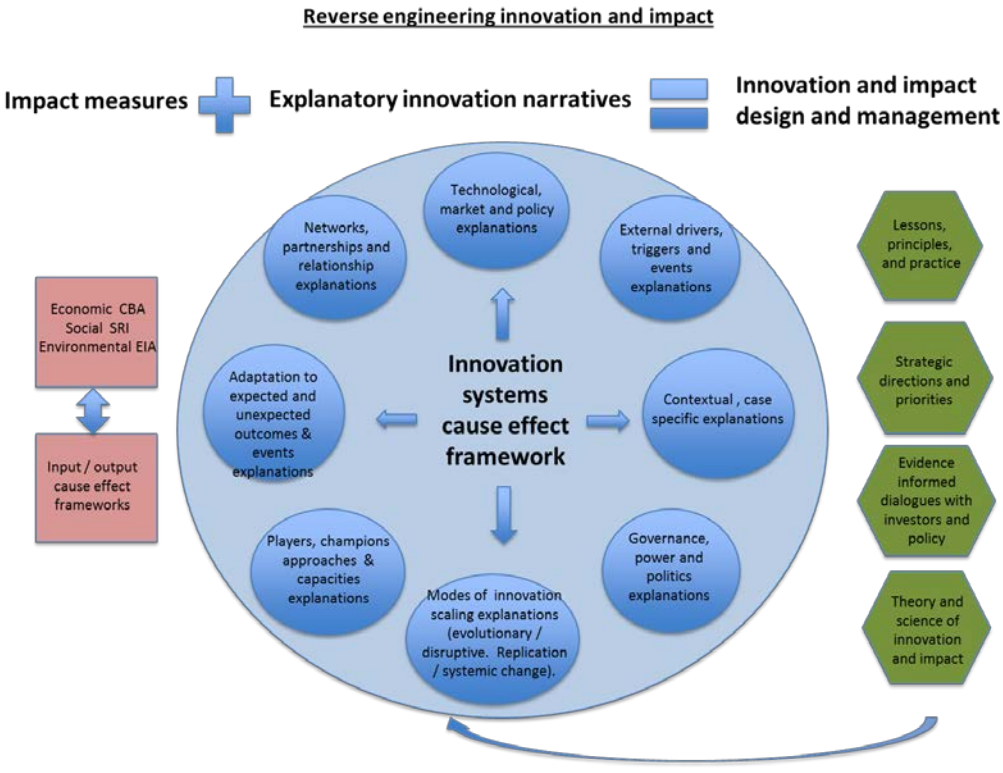


**Figure 1: Conceptual framework for links between innovation configurations and impact**

## Case studies – Preliminary results

The following are brief descriptive summaries of the case studies undertaken.

**1. Water use efficiency (WUE) in Queensland, Australia.** Public policy stimulates technical and institutional responses that drive innovation and create pervasive impacts. Underpinned by a deep alignment between state government, industry and conservation groups. Operationalized through a government established consortia of industry, conservation, and research agencies. Resulted in step change improvements in water use efficiency and profitability across the sector after five years. Consortia subsequently adapted to tackle fertilizer and pesticide run-off issues.

**2. Forage research in Indonesia**. Research-led interventions to identify, test, and scale best-bet technologies had limited long term impact due to a lack of complementary public investments to sustain technology promotion. Involved a series of research and technology promotion projects between CSIRO and Indonesian universities over a ten-year period. *Ex-post* impact assessments predicted significant economic returns. However, the sustainability of the project's achievements through government schemes was weakened by transfer of key government personnel and subsequent lack of policy support.

**3. East coast fever infection and treatment method.** Technological breakthroughs from the 1950s and 1960s overshadowed by frontier science research agenda of key agencies, failed to get put into use until a public private sector mechanism in the 2000s created a private sector delivery mechanism. Effective and simple control measures were sidelined by the search for recombinant vaccine solutions in a newly established international research center that failed to produce the needed technological breakthrough. The establishment of GALVmed in the 2000s, as a platform to engage the private sector in the commercialization of public science solutions, eventually formed sufficient political alignment and incentives to create delivery system.

**4. Novacq™ prawn feed.** Novacq™, is a bioactive aqua feed ingredient, produced via the bio-conversion of low-value plant waste from agriculture. Once these technological innovations had reached a proof of concept stage, CSIRO worked in partnership with industry to refine and apply the innovation through a commercialisation partnership. In particular, CSIRO partnered with 3 different commercial businesses (2 businesses based in Australia and in Vietnam) to develop and apply the patent. Consequently, this feed additive has been patented and licensed for use by prawn food mills both in Australia and worldwide. In addition to this, because Novacq™ uses marine organisms to convert carbon in the waste into

materials that are harvested, dried and used as the food additive, it has opened up a new market in agricultural waste which was did not exist before.

An independent economic impact assessment by *ACIL Allens* in 2014 reported that the licenses on these product innovations are creating significant market disruption in Australia and a number of Southeast Asian countries. In the case of a small to medium Vietnamese business, the initial combination of technological and institutional innovation led to one of the biggest partnerships in CSIROs aquaculture research portfolio and opened opportunities to improve the health of their shrimp and improve disease resistance in Australian Prawn Industry to continue its sustainability. An *ex-post* evaluation indicate that the cumulative economic benefits of Novacq™ are estimated to be $368 million between 2014 and 2023/24.[3]

**5. ISPC review of Agricultural Research for Development (AR4D) innovation partnership practice.** Multi-stakeholder processes enabled through innovation platforms deliver project-bound impacts at local scales (Box 2).

**Box 2: AR4D partnership practice**

A review commissioned by the CGIAR ISPC explored multi-stakeholder practices in ISPC in relation to the contribution of agricultural research to the sustainable development goals (SDGs). The review notes that agricultural innovation systems (AIS) was embraced by the international agricultural research community, but was hybridized with an existing alternative perspective: farming systems, farmer first and participatory ideology more generally. These two perspectives explicitly and implicitly suggested that agricultural development could be progressed by optimizing the farming environment from within. This caused AIS perspectives to be focused on the micro-scale conditions needed enable innovation. The key manifestation of this is the now ubiquitous innovation platform as the central project implementation approach of so called "innovation systems" research approaches.

The rhetoric of these approaches in agricultural research for development acknowledges that wider institutional and policy change and conditions are an essential element of the innovation process. However, generally only very limited attention is paid to this context. Where it is included in narratives of how change would take place, it has been suggested that local level innovation processes could have catalytic changes on wider policy and institutional settings. Ideas such as strategic niche management support this position. There are, however, limited examples of this process taking place in practice in the agricultural sector, and certainly not through a purposeful approach of enabling local innovation as the key intervention point. Local experimentation with innovation processes remains an important element of transformational change, but the operational framing for this is usually absent and it has been difficult to achieve impact at scale.

Source: ISPC, 2015. *Strategic study of good practice in AR4D partnership*. Rome, Italy. CGIAR Independent Science and Partnership Council (ISPC), viii + 39pp + annex 49pp

[3] *ACIL Allen Consulting, 2014. CSIRO's Impact and Value – An Independent Assessment.*

**6. Foot and Mouth Disease (FMD) eradication in the Philippines.** Results from economic analysis provided the basis for public and private sector dialogue to facilitate synergistic investment into effective disease eradication. Publicly funded research and economic analysis provided "evidence" that FMD eradication in the Philippines would yield sufficient returns to expected costs, and therefore offered a worthwhile investment of public funds. The analysis also showed that while control and eradication would be beneficial to smallholder producers, a significant portion of the benefits would accrue to the large-scale commercial livestock sector. Eradication is not a one-off investment but requires continued investment to protect the FMD-free status of the country, once achieved. Sustained public funding of the necessary FMD surveillance and control would have been difficult to justify, particularly given the commercial orientation of the expected benefits. These results not only suggested that considerable scope existed for the government to involve the private sector more actively in financing national FMD control efforts, but also provided a platform for dialogue between the public and private sector. This dialogue resulted in the direct participation of the commercial sector in the national FMD eradication Task Force and agreement on long-term complementary public and private sector investment in eradication and control activities and facilities. The system established and the subsequent eradication of FMD in 2011 continues to deliver productivity improvements, impact to smallholders, and access to new markets for the livestock sector as a whole.

**7. Index-based livestock insurance (IBLI) in East Africa.** Modelling and GSI science breakthroughs coupled with risk analysis of pastoralists, created opportunities for a new insurance product requiring a capacity-building support facility in a research organization to incubate the product with SMEs backstopped by policy support. Initial piloting with incumbent insurance industry player failed as it competed with existing products. Shifting its attention to insurance, the SME was more successful but required the establishment of a capacity-building unit by ILRI. This has allowed the incubation of a commercially viable risk management innovation. The incubation facility in ILRI and its underlying modelling and GSI science platform have the capability to develop new, related solutions and incubate these with SMEs.

**8. Innovation support in Latin America.** Lack of synergy among the public and private sectors and civil society leads to missed opportunities for pervasive impacts from rural development investments. In an attempt to build on, and link to, a wave of innovation that transformed Peru's coastal zone into a global production hub for high-value horticultural export crops, the World Bank and the Peruvian government conceived a project to stimulate the modernization of smallholder agriculture in the Peruvian highlands. The resultant program was based on the provision of incentives and competitive grants for demand-led agricultural research, private sector technology transfer, and building of concomitant institutional capacity. While the

ten-year investment improved the livelihoods of smallholders within the scope of the program through the increased relevance of, and access to, services including research and technologies, it never attained its intended transformative impact. Given its relative success in building local capacity and the engagement of smallholder farmers, however, INCAGRO-type projects quickly became a template for agricultural investment programs in the region. These include the PISA program in Bolivia and the RESEPAG investments in Haiti. In the absence of strong alignment among the public, private and tertiary sectors, key to Peru's coastal zone transformation, this seems to have locked the region into local agricultural system optimization investment with relatively marginal development impacts. This observation is further supported by experiences from Chile, which for many years was the region's shining innovation light during an era of strong synergy between the private and public sectors. In the absence of such alignment, however, subsequent investments to rekindle such systems' transformation have largely failed.

**Table 1: Patterns of innovation and impact processes**

| Cases | Initiator | Critical features | Role of research | Operational alliances | Strategic alignment of stakeholders at sector or national level | Solution, product or system innovation | Scope of impact |
|---|---|---|---|---|---|---|---|
| **Forage research and adoption project** | Project commissioned to scale research findings | Extensions methods and farmer organizational development promotes technology | Development and evaluation of technology and farming systems options | Local research and extension organizations and farmers groups | Weak links to private sector. Links to local and national policy agencies vulnerable to project close and political cycles | Created local farming systems solution with limited spread | Limited to project domain |
| **AR4D innovation partnership practice** | Projects commissioned develop research informed production and value chain solutions to improve poor smallholder livelihoods | Multi-stakeholder processes enabled through the use of innovation platforms | Research convenes stakeholders to develop and test client oriented solutions | Mainly research and local farming, value chain and development stakeholders | Rarely tackled and usually absent | Local production and value chain innovations that struggle to scale | Limited to project domain |
| **East coast fever** | Research commissioned to solve major livestock disease | Low-tech solution ignored for decades. Commercialization only achieved by the establishment public private sector platform GALV MED | Development and validation of solution | Alliances initially absent, but latterly GALVmed facilitated partnership with the private sector | Considerable policy commitment to provide solutions aligned with commercial opportunities for treatment delivery | System innovation to deliver product and service innovation | Potential for sector wide impact |

| Cases | Initiator | Critical features | Role of research | Operational alliances | Strategic alignment of stakeholders at sector or national level | Solution, product or system innovation | Scope of impact |
|---|---|---|---|---|---|---|---|
| **Index-based livestock insurance** | Research commissioned to find risk management solutions to climate variability for poor pastoralists | Creation by international research organization of an innovation incubator to build capacity of SME to commercialize insurance product | Develop, testing and refinement of the product, SME capacity development and policy engagement, impact tracking | Shifting alliances of research, first with large incumbent industry players and then more successfully with SMEs for piloting and proof of concept | Initially weak, but policy shifts and donor investment have created strong alignment between public and private sectors on livestock insurance | Product innovation, with some evidence of market disruption. Potential to part of financial service for the poor systems innovation | Pilot scale with sector wide impact potential |
| **Novacq™** | Applied research develops bioactive aqua prawn feed | Commercialization with Australian and Vietnamese businesses, at a time of rapid, publicly backed aquaculture sector growth | Technology development, licensing and trouble shooting and incremental improvement | Partnership between research and SME | Strong alignment with public investment in aquaculture sector development | Product innovation that is creating significant market disruption. Now licensed in Australia and a number of Southeast Asian countries | Large-scale economic and environmental impacts already documented |
| **Agricultural big data in Australia** | Technological advances in data capture and analysis create opportunities decision support systems | The private sector has driven much of the application investment in data capture and proprietary use | Development of platform science and application development | Mainly alliances between companies | Weak alignment across stakeholder groups reinforces incumbent industry positions and limits creation and sharing of wider benefits | Product and service innovations. Currently insufficient alignment to create system innovations | Sector wider impact potential but policy and institutional innovation still lagging |

| Cases | Initiator | Critical features | Role of research | Operational alliances | Strategic alignment of stakeholders at sector or national level | Solution, product or system innovation | Scope of impact |
|---|---|---|---|---|---|---|---|
| **FMD** | Cost benefit research reveals opportunities for private and public investment and collaboration | Clear evidence of benefits for the private sector stimulates investment in control measures that also have no cost benefits to smallholders | Testing and validating control measures. Monitoring disease incidence | Mainly among, public sector veterinary services, private sector producers and exporters and smallholder in the implementation of system-wide control and eradication measures | Strong alignment between public and private sector at a national level with significant public investment in infrastructure | System innovation in the form of a sector wide FMD eradication, monitoring and control regime | Sector wide impact with significant economic and social returns |
| **WUE** | Public policy shift in response to prolonged drought and wider sustainability concerns about agricultural practices | Involved a coalition of policy, industry, civil society and research agencies seeking radical solutions deliver sustainability with profitability. Anchored around a simple common monitoring performance management systems | Development, testing and validation of existing and novel WUE solutions | Wide ranging multi-stakeholder partnership | Policy driven, but with very strong alignment of stakeholder agendas at strategic and operational levels | System innovation enabling the deployment of technical and institutional innovations across the sector | Sector wide impact with significant economic and sustainability returns |

| Cases | Initiator | Critical features | Role of research | Operational alliances | Strategic alignment of stakeholders at sector or national level | Solution, product or system innovation | Scope of impact |
|---|---|---|---|---|---|---|---|
| **Innovation support – Latin America** | Perceived opportunities to modernize smallholder agriculture through farmer-led innovation and development | Competitive R&D service grants for farmer groups | Implement farmer-demand-led adaptive research priorities | Local research and extension organizations and farmers groups | Weak operational linkages with private sector and national policy actors | Local farming system solutions, generally with limited applicability | Limited to actors directly involved in the program |

## Patterns of innovation and impact observed in the case studies

Table 1 above presents a comparative analysis of the case studies. Although limited in number, we believe that the case studies illustrate three very broad patterns of innovation each with distinctive configurations and processes and each with different scope for scale of impact. Namely: (i) Incremental innovation and system optimization; (ii) Radical innovation and sub-system transformation; and (iii) Transformational innovation and systems transformation (see Figure 2 and descriptions below). This innovation typology draws the work of Freeman and Perez (1988), the graphical representation in figure 1 draws on the work of Weterings et al (1997 and subsequent elaboration by Frank Geels and followers, for example Geels, (2002). Scrase et al (2009) provide a valuable application of these perspectives in relation to agriculture and food system transformation in the UK.

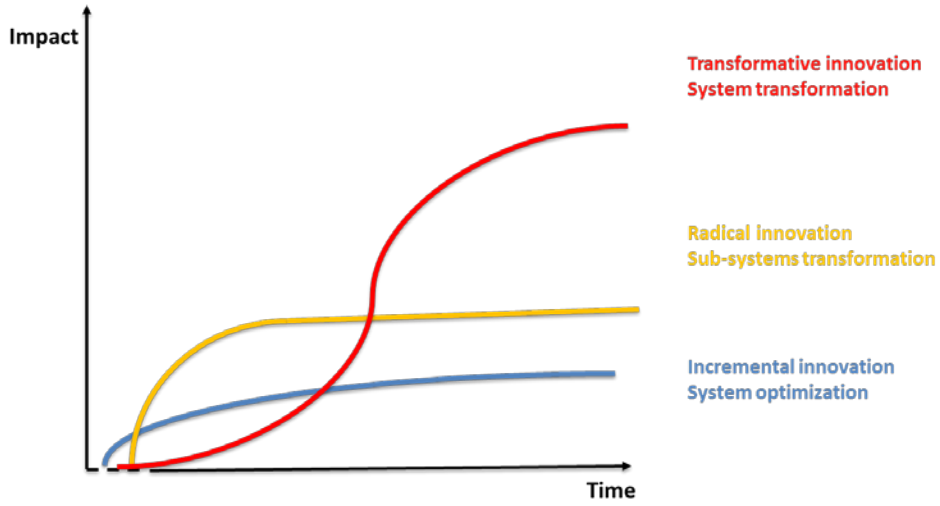


**Figure 2: Modes of Innovation and impact**

### Incremental innovation and system optimization

The forage case, the AR4D innovation partnership and platform, and the innovation support in Latin America illustrate the way research helps develop incremental improvements in existing farming systems and individual value chains. These deliver valuable local improvements to livelihoods of smallholders and profits for value chain actors. Demand-led research and collaborative action by local stakeholders are critical in defining and developing solutions. The scale of impact, however, is often restricted by the absence of policy, institutional and market systems changes and investments needed to spread and sustain these innovations.

***Key characteristics*:** Incremental improvement of existing products and services or incremental improvement of value chain efficiencies that deliver localised social, economic and environmental impact in specific production systems and value chains.

**Radical innovation and sub-system transformation**

The Novacq™ case, the FMD case, the East Coast Fever and the index-based livestock insurance (IBLI) cases illustrate ways in which new types of products and services have created step change improvements in specific sub-sectors. Mission-focused research and other interventions have provided radical innovations to generic sub-sector challenges, followed by incremental innovations to improve effectiveness. All demonstrate a degree of sub-system transformation. For example, in the Novacq™ case the aquaculture feed market has been disrupted and new alliances have been developed between Vietnamese and Australian companies. The FMD and East Coast fever examples have involved considerable collaboration between the public and private sectors to create delivery and control systems, and infrastructure, respectively. The IBLI case is more nascent, but it has involved a new type of innovation incubation approach in an international research center as well as changes in different parts of the market to accommodate the new product. All cases open up new economic and other value-add opportunities, new incremental innovation opportunities in production and marketing systems, and opportunities for the delivery of a wider range of products and services through the delivery systems established.

***Key characteristics*:** Technological and/or market "step jumps" or discontinuities that open up new economic, social and environmental impact opportunities in a specific sub-sector or market sector and open up new opportunities for incremental innovation.

**Transformative innovation and system transformation**

The water use efficiency (WUE) case and potentially the big data case illustrate far-reaching, deep types of innovation with pervasive implications for the entire agricultural sector. These cases are not demand driven *per se*, but emerge from a broad-based consensus on the need to pursue new directions or take advantage of new platform technologies. In the WUE case, the combination of policy-push, technical and institutional responses, and innovation has extended the frontiers of both profitability and sustainability of the sector. The high level stakeholder and political alignment and the organizational arrangements put in place to advance this transformation have also been used to address other sustainability challenges, notably fertilizer and pesticide run-off. The Australian agricultural big data case is at a more nascent stage, although an emerging suite of decision support applications and related economic opportunities is evident. However, unlike the WUE case the degree of stakeholder and political

alignment needed to create the step change in economic, social and environmental gains that the technology promises.

***Key characteristics*:** Deep systems changes underpinned by broad-based consensus that significantly advance the economic, social and environmental frontiers of the agricultural sector as a whole, and that open up opportunities for new waves of radical and incremental innovation.

## Discussion

1. Much of the received wisdom on innovation good practice and its link to impact is evidenced in the case studies. This includes: (i) the importance of responding to client demand; (ii) various forms of partnerships and alliances and the need for collaboration between public and private sectors; and (iii) the importance of science, technology and research as both initiators and enablers of innovation.

2. The story, however, is more nuanced than that. Our case studies tell us that the overriding ingredient in innovation processes that have pervasive impact and lead to transformational change do not relate to the fine-grained arrangements involved in the innovation processes *per se* (although these are critical implementation strategies). Rather they tell us that the main ingredient is macro level alignment of public policy, private, and often civil society objectives. This alignment may be hard won, but is critical for deep change and impact.

3. This suggests that there is a political economy dimension to the willingness to mobilize resources, coordinate efforts, and get the right mix and sequencing of public and private investments to make transformational change happen. This is particularly important where larger societal issues are at stake such as environmental protection, health, and nutritional and food security.

4. Despite the critical role played by the private sector, purposeful and proactive public investment is evident in the radical and transformative modes of innovation. This involved responding to market failures through, for example, research on livestock diseases important to poor livestock keepers in Africa. It also involves, however, investing in system failures through, for example, investing in the creation of a mechanism to bring industry, conservation and research players together to tackle water use efficiency in Queensland, Australia. Therefore, while the public sector must invest to reduce risk, it must also invest to reduce uncertainty and create new futures.

5. The three modes of innovation discussed all have a value in progressing equitable and sustainable economic growth, albeit with different scales of impact. These

modes also highlight the way clusters of policies, practices and stakeholder interests can lock agriculture into incremental innovation and system optimization at a time when step changes are needed. It therefore also presents a framework for allocating scarce public and private sector resources in ways that open up new opportunities for innovation and impact.

6. We argue that this resonates with the original intent of innovation systems and indeed recent writing on innovation policy; for example, the "entrepreneurial" state, (Mazzucato, 2015); and ODI's the politics of innovation (Mason, et al 2016). This also resonates very strongly with the work of Donella Meadows on stages of transformation (1997). However, much of the intent innovation systems perspective has been lost in its in international agricultural development. This has led to misallocation of resources and policy attention towards local optimization at the expense of systems transformations needed to reinvent the agricultural sectors that many of the world's poorest still rely on.

7. One symptom of this is that public (but also industry body) investments have given primacy to addressing the immediate needs of farmers. At one level this client orientation is laudable. An over-emphasis on demand-led, bottom-up processes and short-term impacts at the farm scale, however, has skewed the allocation of public resources towards this local optimization route. Innovation must always end with impact at local level, but local impact is not going to drive the transformative changes that developed and developing countries are seeking.

8. System optimization allows poor farmers to improve their livelihoods marginally but it rarely leads to a transition out of poverty. In the developed world, it sees, for example, profits eroded, a sunset industry, out-migration, and skewed age distributions in family farming. Rural sociologists increasingly refer to this as the individualization of development (Quisumbung, 2003). In other words, the public sector opting out of the responsibility of tackling the grand challenges we face by assuming that individual actors in economic systems can achieve the transformational changes required on their own.

9. The appropriate mix of public and private sector investments needed for transformation require agreement on what are the critical challenges ahead and this in turn requires strategic partnership between public, civil and private sectors at a political level. The global agreement to the Sustainable Development Goals (SDGs), perhaps, sets the framework for such processes. In reality for many countries these goals have been eclipsed by more immediate and local priorities and political imperatives where national economic growth trumps more altruistic global ambitions.

10. In summary, insights from this study suggest that (i) innovations systems as a concept and policy framework cannot usefully be scaled down to local contexts; (ii) much greater attention needs to be given to developing political alliances between public and private sectors at a macro level; and (iii) major agricultural research organizations not only have a role in science-informed brokering of such alliances, but have urgent need to engage much more proactively in addressing policy failings in the wider enabling environment and the misguided dominance of local optimization perspectives in much public investment.

Tables 2 and 3 present a framework for navigating and progressing across the modes of innovation articulated by this study.

**Table 2: Typologies of innovation modes**

| | Incremental innovation | Radical innovation | Transformational innovation | Paradigm innovation |
|---|---|---|---|---|
| ***Focus*** | Systems optimization | Sub-system transformation | System transformation | Systems replacement |
| ***Key features*** | Continuous improvement of existing products and services in current production systems and value chains | Technological and/or market "step jumps" or discontinuities that enable the creation of new products or service but restricted to a sub-sector or existing market segment | Deep systems changes that significantly affect the agricultural sector as a whole enabling the creation of new classes of products and services | Paradigm changes that potentially affect all sectors of the economy |
| ***Impact scope*** | Incrementally improves social, economic and environmental impact with in system limits | Significantly expands economic, social and environmental impact in a specific sub-sector or existing market segment | Unlocks new economic, social and environmental impact possibilities across the agricultural sector | Reframed global limits to growth |
| ***Trajectory*** | Creates understanding of technological and system's limits that need to be addressed | Creates opportunities for next wave of incremental innovation in agricultural sub-sectors or market segments | Creates opportunities for next wave of radical and incremental innovation in the agricultural sector | Creates opportunities for transformative, radical and incremental innovation in all economic sectors |
| ***Defining processes and practices*** | Demand-led priorities setting and user led co-creation of solutions informed by research coupled with participatory processes and governance | Alignment of business and policy incentives and agendas allows commercialization of technological breakthroughs addressing defined problems and opportunities | Public, private and civil society's alignment around new directions to tackle critical societal issues involving uncertainty and complexity | Global uncertainty. The search for unimagined futures |
| ***Policy framing*** | Science and technology | Sub-sector innovation policy | National Systems of Innovation | |
| ***Case study Examples*** | Forage in Indonesia,<br>AR4D innovation platform projects | Novacq™, IBLI,<br>FMD control | WUE,<br>(Australian Big Data) | Digital revolution<br>Advanced materials |
| ***Timeframes / phasing*** | Continuous | Discontinuous events | Periodic tipping points | Epochs with shortening cycles |

**Table 3. Practice and policy considerations in different innovation modes**

| | Incremental innovation | Radical innovation | Transformational innovation | Paradigm innovation |
|---|---|---|---|---|
| ***Realm of applications*** | Continuous upgrading and improvement of existing production and value addition processes | Defined sub-sector challenges where game changing technological breakthroughs and other advances exist or are likely | Complex, contested concerns at the sector or societal level | Creating new futures |
| ***Public investment rational*** | Market failure | Market and systems failure | Systems failure and uncertainty | Uncertainty |
| ***Tensions to be managed*** | Over investment in immediate improvements jeopardizes long-term opportunities | Reinforces position of incumbent market players at the expense of emergent players with strong innovation potential | Conflicts between emerging and incumbent stakeholders in reaching consensus and implementing joined-up action | The future is unknown and unknowable |
| ***Limiting factors*** | Local vested interests | Effective public private sector partnerships<br>Social license | Lack of consensus at societal level<br>Clarify on public and private sector roles and investments | Investment for societal good |
| ***Characteristics of tools and approaches*** | Need to bridge scales.<br>Needs a stronger political economy perspective<br>Need to support experimentation in both the technology sense and the impact effectiveness sense<br>Need to help navigate the transition between local optimization and transformation, including tools for integrated diagnostic analysis of systems to be transformed<br>Need to help with alignment of stakeholder agendas and consensus building | | | Need to assist in building imagined futures |
| ***Innovation capacity metrics*** | Rural innovation capacity | Ability of players to respond to sub-sector challenges and opportunities | Agricultural innovation systems health | |

## Caveats, challenges, and next steps

1. These are preliminary findings from a modest evidence base. There is a need to further expand the evidence base, including making more use of documented quantitative economic impact assessments, validating the framework with more cases, and accounting for potentially contradictory cases.

2. The evidence and insights from this current work suggest that we need adjust our analytical framework to get a better sense of political economy and governance issues and alignment and their relationship to impact. Figure 3 suggest a conceptualization for that reframed analysis.

3. New tools will be needed to help navigate the transition between incremental, radical and transformational modes of innovation. The emphasis, however, needs to be less on tools that assist with contextual design of local innovation processes – there is already an abundance of these. Rather the emphasis needs to be on tools that drive organizational strategy and priorities. In particular, tools that help public, private and civil society organizations collectively negotiate the shape and direction of the innovation trajectory as a whole and the alignment of policies and process around a relatively small number of key challenges. The difficult part of this task is that the future direction cannot be constructed around current realities nor necessarily around user and client demands. Instead, it needs to be built around imagined futures that provide a reframing of the technology, business, and policy mix needed to achieve these futures.

4. Guiding principles for new tools:
   (i) Need to bridge scales.
   (ii) Needs a stronger political economy perspective.
   (iii) Need to support experimentation in both the technology sense and the impact effectiveness sense.
   (iv) Need to help navigate the transition between local optimization and transformation, including tools for integrated diagnostic analysis of systems to be transformed.
   (v) Need to help with alignment of stakeholder agendas and consensus building.
   (vi) Need to assist in building imagined futures.

5. The recognition of different modes of innovation presents new challenges for benchmarking innovation capacity and performance. In particular, the ability to identify and assess lock-ins and ways of “measuring” the capabilities, alliances, investments, and systems needed to progress transformational innovation.

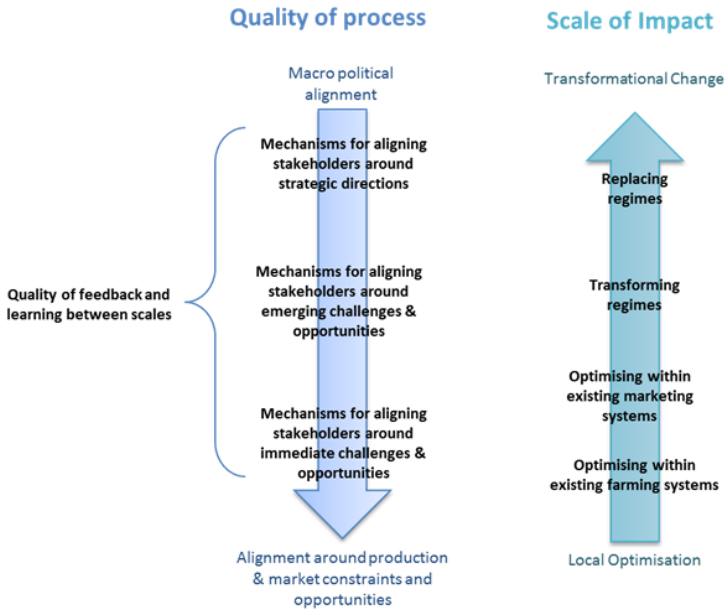


**Figure 3: Relationship between process and impact**

## What does this all mean for agricultural research organizations?

1. Agricultural research organizations will need to play an expanded number of roles, implying both new tools but also new capabilities, including: (i) brokering alignment; (ii) science-informed foresight; (iii) science discovery to populate the sector with transformational enabling technology; (iv) managing the iteration between technological opportunities and market and social application on the big challenges that alignment coalesces around; (v) research into, and brokering of, new policy and institutional frameworks that enable more effective innovation processes.

2. Research organizations will need to undertake new forms of experimentation. For example, pilot mechanisms to provide facilitative support to sub-sectors that are seeking to transform. This is different from the current focus on incubating innovation at the firm and technology scale. The new focus is on incubating systems innovation to help transform sub-sectors and even sectors. This is ambitious but necessary.

3. There is still an ongoing need to continuously learn about the effectiveness of nuts and bolts practices and strategies. The caveat is that these should also be used to highlight underperforming organizational strategies and structures, routines and practices that are prone to lock-in and system optimization.

## References

Freeman C. and Perez C. (1988) 'Structural crises of adjustment, business cycles and investment behaviour', in Dosi G., Freeman C., Nelson R., Silverberg G. and Soete L. (eds) *Technical change and economic theory*, Pinter, London, pp. 38-66.

Geels F.W. (2002) 'Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study', *Research Policy* 31, 1257-74.

Mazzucato, M (2013) *The entrepreneurial state: debunking public vs. private sector myths,* Anthem Press.

Meadows, D. (1997) Places to intervene in a system. http://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/

Michael Robertson, Brian Keating, Daniel Walker, Graham Bonnett and Andrew Hall (2016) Five Ways to Improve the Agricultural Innovation System in Australia. *Farm Policy Journal, vol 15, no 1*

Quisumbing, A. R. (ed) (2003) Household decisions, gender, and development: a synthesis of recent research 2003 pp.xv + 274 pp. International Food Policy Research Institute (IFPRI), 2033 K Street, NW, Washington, DC 20006-1002, USA.

Scrase I., Stirling A., Geels, F.W., Smith A. and Van Zwanenberg P. (2009) *Transformative Innovation: A report to the Department for Environment, Food and Rural Affairs*, SPRU - Science and Technology Policy Research, University of Sussex.

Weterings R., Kuijper J., Smeets E., Annokkée G.J. and Minne B. (1997) '81 mogelijkheden: Technologie voor duurzame ontwikkeling' ('*81 possibilities: Technology for sustainable development*'). TNO report for VROM (Ministry of Housing, Spatial Planning and Environmental Affairs), The Hague.

World Bank **(**2006). *Enhancing Agricultural Innovation: How to go beyond the Strengthening of Research Systems*. Economic Sector Work report. The World Bank: Washington DC pp. 149

*World Bank 2012. Agricultural Innovation Systems: An Investment Sourcebook*, World Bank: Washington, D.C

## Annex 1: Framing the case studies.

**What do we already know about agricultural innovation?**

Conceptual development on understanding how agricultural innovation takes place is now quite mature and considerable work has been done on elaborating the idea of agricultural innovation systems. Key points include the following:

- Innovation is not research or technology but often involves both.
- Its critical feature of innovation is not novelty in the sense of invention, but novelty in the sense of putting ideas into use in new ways for economic and social gain.
- Innovation can involve technological change, business model change and policy change and is usually a combination of these.
- Innovation emerges from dense networks of interaction and this often involves a two way interface between knowledge creation and knowledge use by farmers or companies.
- Innovation is a multi-scale phenomena with for example technological changes at the farmer level being co-dependent on accompanying changes, markets and policy regimes.
- Innovation rarely a linear predictable process of ideas-application-impact. Instead it involves complex pathways and chains of events with innovation trajectories unfolding in unpredictable ways often over long time frames. This often involves feedback loops where ideas are refined and applications are adapted to be fit for purpose.
- Innovation capacity has multiple dimensions. (i) Skills in research, business practice and management. (ii) Routines and learnt behaviors of organization that help in creating interfaces with sources of ideas and partners. (iii) Links, networks, partnerships and alliances that connect players, allow ideas to flow and help in the co-construction of conditions to use those ideas. Policy regimes that encourage innovation through incentives, investment and regulation.
- The roles of the public and private sectors is neither mutually exclusive nor fixed. Instead the role of players evolves during the innovation process, with configuration of players adapting to the contingencies of opportunities and challenges being addressed.

- The innovation creates winners and losers. As a result politics, power and competing agendas shape the pace and direction of innovation as dominant stakeholders jostle to capture new opportunities or to maintain the status quo where it is to their advantage.

**How do we use these ideas in our case studies to arrive at an accessible narrative of innovation that can form the basis of a pragmatic framework to guide decisions, practice and policy?**

The points above provide some conceptual orientation for the case studies. However what is needed a common format is needed for the innovation stories so that innovation story writers have some way of organizing information collected. Themes to be explored include the following:

**An historical perspective.**
The account needs to be historical in orientation. For cases strongly associated with research organisations this will inevitably mean going back to foundational research and following the trajectory of players, partnerships and interconnected events unfold over time. For the investment stories in innovation support funds and facilities etc, it will probably need to start with initial design features and then following how these worked over time and what was learnt.

**Technology and other inputs**
The account needs to include technology, but also identify the things other than technology that contributed to innovation taking place: market responses, policy changes, institutional developments, capacity building and training.

**Who was involved in doing what?**
The account needs to tell us about the role of research in the unfolding trajectory and the way (if any) this role was altered in response to the context of the innovation process. What is the type of research, foundational, experimental, or applied? Which other organisations were involved and what was their role over time.

**Networks, partnerships and alliances.**
What was the pattern of links that connected different players? How and when did these links emerge? Where there formal partnerships or were informal networks also important. Did these evolve over time and why, and what allowed this to happen.

**Skills and capacities.**
What skills, routines and practices were valuable by key organizations involved in the innovation process?

**Triggers, key turning points, pivots and decisions.**
Where there any key turning points and if so why where they important? What sort of decisions did different organisations need to make? How did different players involved in the innovation process respond to critical events and opportunities?

**Links between actions and outcomes.**
What were the causal links that where observed. What lead to what? Where there any notable milestones, choices or decisions that were critical to success? What was the mixture of direct out comes from purposeful actions and outcomes that were enabled by external circumstances. Attribution versus contribution tensions in narratives.

**Enablers of innovation.**
What events, practices, policies and individuals smoothed the path to innovation? Where there champions that helped drive the process along? Which organization were they in? Did they have alliances with other key players?

**Pain points and challenges**.
Unhelpful M&E and performance measurement. Organizational policies and culture that challenged working with at the research-development- market interface. Lack of capacity. Ineffective networks. Political challenges and contestation. Entrenched perceptions about the role of the public and private sectors. Policy and regulatory bottle necks. Incoherent and conflicting polices.

**Diversity and contestation of values and perspectives**
What were the motivations / intentions / agendas held by different actors/organizations within the innovation process? How does this influence the process of innovation / change over time? How were conflicting values/priorities negotiated (or not)?
How do different stakeholders/actors perceive 'success' and impact? I.e. what are different perspectives and experiences of successes or the impact of the tech/institutional change? How inclusive was the innovation process of different stakeholders/actors?

**Wider context and stakeholder agendas**
How did the broader context influence, (re)shape the trajectory of innovation over time? E.g. political and organizational agendas (and the power dynamics of these); funding environments; significant events; (e.g. GFC/natural disaster etc.) …could set constraints or provide opportunities
How did stakeholders within the innovation process respond and adapt to the broader context?
How did different stakeholders/actors understand and (re)interpret the interventions and changes that are being suggested? (I.e. adaptations, adjustments to the technology/institutional environment that were not intended/anticipated)

How the initiative was positioned in the organisations of the key stakeholders … an experiment off to the side, a core part of business, etc.

**Judging success**

The account needs to talk to the question of what success looked like and who decided that success looked like that. Final evaluations and similar can give some tangible feeling of the success of the innovation story. How was success measured where there alternative narratives of the success or failure by different groups. How was success evidenced? Were there winners but also looser, where there any negative social consequences or how were these mitigated?