Science, Technology and Society

Volume 25 Number 2 July 2020

Los Angeles | London | New Delhi
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Aims & Scope

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Science, Technology and Society

This journal is partially supported by Research and Communication Division, Ministry for Development Cooperation (The Netherlands).

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Special Issue: Responsible Research and Innovation in the Global South: Agriculture, Renewable Energy and the Pursuit of Symmetry

Guest Editors: Poonam Pandey, Govert Valkenburg, Annapurna Mamidipudi and Wiebe Bijker

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Responsible Research and Innovation in the Global South: Agriculture, Renewable Energy and the Pursuit of Symmetry

POONAM PANDEY, GOVERT VALKENBURG, ANNAPURNA MAMIDIPUDI and WIEBE BIJKER

In contemporary, industrialised and industrialising cultures, science and technology have become an inseparable element of our existence and socio-cultural endeavours. The technological cultures that we live in, make us empowered and vulnerable at the same time (Bijker, 2006; Hommels et al., 2014). To accommodate the uncertainty that is inherent in innovation processes and outcomes, it is generally considered beneficial to enrol multiple perspectives and ways of seeing and understanding the world, when looking for innovative solutions to specific problems. Since some ten years, this often happens under the banner of *Responsible Research and Innovation* (RRI). This special issue originated from such an effort. Funded by the Netherlands Organisation for Scientific Research (NWO), and with the collaboration of Maastricht University and the Indian wing of the Dutch chemical company

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Science, Technology & Society 25:2 (2020): 215–222
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820902961

DSM, we set forth to study the responsible innovation (RI) of biogas in a number of Indian villages in a two-year research project (2015–2017). This RespInnBio[1] project engaged with a technological innovation for the use of surplus rice straw as a feedstock for biogas production. Currently, the straw is being burnt in large amounts on the farmlands in the northern parts of India. Over the course of two years, we conducted a number of meetings. We enrolled various stakeholders, and we used various formats for the meetings-dialogue, seminar, workshop, conference and public discussion. Our final conference held in September 2017 provided a pivotal moment towards this special issue.

The involvement of stakeholders and the inclusion of multiple perspectives is not a straightforward matter. The editors of this special issue want to make a plea to pursue symmetry when including such various perspectives: to treat different perspectives and knowledges, at least a priori, symmetrically. When doing so, we do not use the word 'symmetry' to convey some sort of sanitised perfection or a sense of utopian equality. On the contrary, it is our intention—in line with much STS scholarship—to articulate the politics and power structures that would otherwise be hidden under seemingly neutral academic conceptions. We can shed light on the complexity, messiness and imperfections of the world we study, only if we bracket the dominance of our academic conceptions and treat them in symmetry with the knowledge systems we study.

The burning of rice straw in the north of India has become a massive problem—not only social but also political and environmental. In the months of October and November, when harvesting of rice takes place, the national as well as international media are full of critical reports about the issue. These reports often criminalise farmers and blame authorities for inaction. Along with various versions of the problems, the newspapers also report multiple innovative solutions. These include the production of straw-based bioenergy, which is thought to simply remedy the situation. Even though each year the discussion around this issue is enormous, we have also noticed over the past five years (beyond our formal project period) that after the harvesting season, when the smoke dissolves, the tension around straw burning always declines—only to return again the next year.

This leaves us with many questions. Why does issue of straw burning not get resolved, despite the recognition of the problem and availability of solutions? What are the implications of linking energy futures to agricultural futures in relation to vulnerability of technological cultures? Among the multitude of problems faced by agricultural and rural communities in India, who decides which problems should be addressed and through what mechanisms? What role do knowledge hierarchy, power and hegemony play in the decision-making processes? Are there notable alternatives to mainstream problem definitions, who creates and owns these alternatives, and how can we mobilise them?

These questions converge to the focus for this special issue: *How can Responsible Research and Innovation be understood in a distinctly Global South perspective?* While the discourse of RRI is not explicitly positioned as exclusively meant for the structures and institutions of Western countries, we do notice that many of the

ideas seem to take some of those Western foundations for granted. In this special issue, we aim to articulate the mismatches between those foundations and a case in what is very much an Indian context. We engage with these questions in relation to agriculture and renewable energy. Our engagement with the responsible interaction of the domains of agriculture and renewable energy is not only crucial for the Global South itself but also contains lessons for RRI in the Western societies where it originated. Importantly, if we care about respecting the carrying capacity of the planet, and about meeting the needs of its inhabitants in a sustainable and equitable way, it is vital that we realise that many approaches to RRI currently involve only a small subset of those inhabitants.

The term responsible innovation (RI) has its origins in the early 2000s national nanotechnology programme in the USA and similar dialogues on emerging technologies in mainland Europe and the UK (Fisher, 2017; Owen & Goldberg, 2010; Rip & van Lente, 2013). The Horizon 2020 programme of the EU eventually formalised it into RRI, through which it became a central element in the European research policy agenda. Building on crucial insights from previously controversial technologies, and insights in uncertainty and lack of knowledge associated to the future, RRI stipulates that research and innovation should be attuned to societal needs through a process of anticipation, reflection, inclusive deliberation and responsiveness (Owen et al., 2013; Stilgoe, Owen, & Macnaghten, 2013). It aspires to be a process through which innovators and societal actors become mutually responsible to each other (Von Schomberg, 2013).

This special issue consists of a set of articles in which the authors explore how such processes can be shaped in distinctly Indian contexts. While the articles do not jointly offer one monolithic answer to the question what responsibility is, a range of different aspects are highlighted. One observation from Tyagi and Kumar is that an appeal to responsibility might in fact hide the shifting of the burden of risk to individuals, away from the collective. Shahare and Thayyil articulate notions of responsibility that seem to underlie existing policy frameworks and show that these are fairly narrowly defined as an economic perspective on the common good. Alternatively, they suggest that enrolling the public in the articulation of common goods would offer a better way to achieve responsibility. Pandey and Mamidipudi & Frahm, following Bijker's (2017) plea for bold modesty, emphasise the role and responsibility of social scientists and researchers in actively participating in making and becoming of things rather than being distant observers. Sharma, in the context of hybrid environmental governance, shows how responsibility articulated in a top-down manner interferes with the practice at the local level.

Learning from one's own experiences as well as mutual learning from each other are among the core themes of this issue. In the context of the Global South, the issues of huge socio-economic disparities, informality, resource constrains, knowledge hierarchies and power asymmetries are known to create hindrance to mutual learning and RRI (De Hoop, Pols, & Romijn, 2016; Macnaghten et al., 2014; Vasen, 2017). The challenge thus is to find ways of mutual learning that are symmetrical. In this special issue, various articles have engaged with this challenge

at multiple levels. In order to learn and innovate in situations of vulnerability and distress, it becomes important that different forms of knowledges are treated symmetrically and are given respect and sincere acknowledgement for their potential to contribute in a meaningful way—a phenomenon often termed 'cognitive justice' (Visvanathan, 2006). Prasad argues that inclusion of knowledges might mean something different in India than it does in the West. Through the case of Systems of Rice Intensification (SRI) in India, Prasad shows how RRI might offer a vehicle for farmers to escape the dominance of scientific knowledge. Valkenburg presents rules of thumb for processes of knowledge connection. These rules aim to accommodate the recognition for knowledges to depend on their own, specific conditions to appear as valuable. Pandey shows how different ontologies entail different modes of caring, which may not survive if techno-scientific rationality retains dominance. In particular, the deskilling of farmers as a consequence of mechanisation sketches a bleak future. Furthering our commitment to cognitive justice, the article by Tyagi & Kumar experiments with a dialogue between a researcher and a practicing farmer, as an alternative to standard academic papers to do exactly that: to seek symmetrical recognition of the farmer's knowledge in its own right.

Inclusive deliberation has often been presented as a magic-wand solution to many problems of our times. RRI also commits itself to inclusive deliberation in relation to articulating and responding to uncertainties and unintended consequences in the future. By inviting everyone to the table, it is assumed, a democratic decision on a problem at stake could be achieved. Several contributions in this special issue engage with the challenges and problems of inclusive deliberation. Shahare & Thayyil and Sharma point towards the 'deficit' models that are still prominent in the functioning of bureaucracy and decision makers in the global south. Often, publics and communities are taken as homogeneous groups who might not be able to make proper decisions due to the lack of 'right' information and knowledge. As a result, decisions are made on their behalf by bureaucrats, policy makers and top-level agents. Pandey highlights that there are socio-cultural constraints such as criminalisation of a social group (e.g., farmers who burn the straw), which entails that even if they are invited to participate, they might not be willing or able to express their concerns in front of a diverse audience. Valkenburg suggests that building arrangements that organise dissensus and contestation rather than consensus might be a better alternative to overcome problems of participation that result from emergent hierarchies of knowledge.

The collection as a whole presents a variety of ways to navigate between, on the one hand, an overly naïve celebration of formal expertise as the true model of knowledge and disregarding other knowledges, and on the other hand a hasty critique of that formal expertise as being hegemonic. By giving due attention to the knowledges held by farmers, whether these are called traditional, indigenous or community-based, the articles jointly show that the tension is much more ramified and complex. Hegemony of formal expertise usually is not only a matter of straightforward dominance and having a stronger say. It is also about rendering the subordinate knowledges invisible, underdeveloped, and in need of

further education. The articles present various forms of symmetry to counter such hegemony. Mamidipudi & Frahm show how symmetricisation renders vulnerability in different ways, which in effect amounts to empowerment of already existing paradigms. Bhaduri & Talat show how information asymmetry is strategically used for competitive advantage, and how a specific asymmetry exists in the denial to local innovations of a site for demonstration of effectiveness. Articulating both asymmetries is a first step towards their mitigation. They also show how practices of frugal innovation result in a fairer balance between user and producer of innovation. Sharma, finally, shows how top-down and bottom-up approaches to a specific innovation both engage only partially with innovation processes. In particular, both fail to recognise that there is a bi-directional construction of the value systems of social groups and the socio-technical ensembles they are part of. Symmetricising this relation opens up new handles for empowerment.

In order to counter hegemony of universalistic, Western models of innovation and development, several articles in the special issue argue for maximising alternatives rather than mainstreaming them. Valkenburg suggests that the best way of maximising alternatives is to encourage representation of diverse viewpoints in deliberations even if they pose contradiction or contestation. For Mamidipudi & Frahm, countering hegemony is in the efforts of STS researchers to encourage ownership of knowledge by local communities that could promote the maximisation of alternatives. Sharma argues that in order to avoid rejection of innovations at the ground, a deeper understanding of diversity and heterogeneity among the members of 'public', 'farmers' and 'community' is essential. A focus on the multiple identities that people mobilise in different circumstances is key in understanding the local dynamics that an innovation encounters.

Contributions to This Special Issue

Mamidipudi & Frahm's article systematically walks us through the RespInnBio project and argues that there is more to RRI than just being a governance framework for techno-scientific innovations. They argue that if we mobilise the principle of symmetry and look at the knowledge-making practices of researchers as well as local actors, then RRI becomes a productive tool advocating epistemic plurality and innovation practices as well as a hybrid governance mechanism that can negotiate multiple meanings of responsibility. In such an arrangement, the role of researchers in STS and RRI also changes. From mere knowledge providers and distant observers, they evolve into actors who facilitate the ownership and circulation of local meanings and ways of knowing, as well as ways to innovate responsibly.

Pandey's article connects the dots between the agricultural modernisation that has been going on for the past few decades, and the 'uncared-for' vulnerabilities generated in these agricultural systems that result in the episodes of straw burning in major parts of northern India. By an engaged to-and-fro dialogue between farmers' responses and scholarly literature, she highlights that straw burning is not just

a problem waiting for a quick fix but a symptom of a deeper civilisational crisis in agriculture that needs careful consideration in the designing of solutions for straw burning. By re-articulating and re-emphasising farmers' vulnerabilities rather than problems caused by burning of straw as the core agenda, this article explores what it would mean for RRI to develop a 'commitment to care', and how RRI researchers could address the ethical-political obligation to bring the marginalised to the fore and help them actively participate in the making and becoming of things.

Tyagi & Kumar, in an unconventional dialogue between a researcher and a practicing farmer, explore the meanings of responsibility associated to the future of farming, its purposes and ends. The core question of their discussion is whether agriculture is something more than a source of livelihood. This question opens up multiple avenues to critically engage with the role of science and technology, the responsibility of a farmer, nature, culture and tradition and multiple relational aspects that make agriculture a civilisational force. Far beyond the dichotomy of glorification of nature, culture and traditional methods *versus* a celebration of modern science and technology, the authors argue in favour of due consideration of the relationalities between different systems. To think about the future of farming and its purposes, we should use identification of complementarities, differences, symmetries, and harmonies to finetune agricultural practices and farmers' engagement with natural systems.

Bhaduri & Talat's article engages with the responsibility embedded in the innovative practices of vulnerable people at the grassroots. The social commitment of grassroots innovators to solve local problems around them with limited resources makes them responsible in relation to sustainable and communitarian practices. The authors argue that RRI can learn inclusion, transparency and frugality from the innovations developed by grassroots actors.

Prasad in his article begins with the question whether RRI has the potential to construct alternative socio-technical worlds or whether RRI too will end up reproducing the status quo. Prasad discusses the case of SRI in India, which is an alternative method of doing agriculture in regions where Green Revolution (GR) farming could not work because of insufficient resources. Many vulnerable farmers have adopted this method and support its claims in practice. However, the scientific establishment seems still committed to the GR paradigm, and refuses to be convinced. They, thus, remain non-supportive of this method. In view of the emergent knowledge hierarchy, Prasad argues, conflicts and controversies become battlegrounds to present and defend alternative world views. In such situations, RRI can prove to be a useful tool only if it is sensitive and reflexive towards the global politics of knowledge making and circulation.

Sharma's article takes the case of social shaping of a solar microgrid in rural India in order to show the tensions between the top-down and bottom-up understandings of energy access, justice and RIs. The top-down narrative considers decentralised solar (renewable) energy as a responsible solution to the energy needs of the people in the rural villages of Bihar in the absence of connection to the central electricity grid. They believed that in the absence of any other options, people might be willing to pay a minimum user fee. However, in the heterogeneous community

of the local village, the most marginalised and poor people asserted their rights as citizens being eligible for free electricity from the state on the basis of their socio-economic status. For these villagers, solar energy is neither responsible nor a solution but rather a 'fake' promise.

Shahare and Thayyil's article presents a critique of the current developments around biofuel innovations in India. They argue that these developments make the goal of RRI for inclusive deliberation extremely difficult to achieve. By critically engaging with the trajectory of biofuel support and development in the policy and scientific circles over the past few decades, the authors conclude that the biofuel development in India is entirely motivated by techno-bureaucratic agenda setting. It is aimed at realisation of techno-economic goals rather than societal needs.

Valkenburg's article engages with the challenges posed by RRI's mandate of inclusive deliberation in settings that have high epistemic and epistemological diversity. He draws on Chantal Mouffe's articulation of contestation rather than consensus as the central tenet of democracy. Applying this to the governance of bio-gasification of rice straw in India, he concludes that inclusive deliberation in RRI in the global south could aim for promoting contestation and presentation of diverse viewpoints rather than consensus building. The latter might unwittingly exclude many marginal viewpoints and knowledges.

Altogether, the collection presents an articulation of the many ways of knowing that seem to matter to socially relevant innovations, and which may not self-evidently find their way into processes of innovation nor into the governance of those processes. The paradox is that RRI often breathes a certain universality in its concerns and approaches, whereas the present collection shows that, rather, particularity is the way to go. Only if particularity is given due attention, will it become clear that also the opposition between 'science' and 'tradition' is a false one. The solution is thus not in simply silencing expertise and giving voice to traditional knowledges, but rather in articulating the various logics with which the various knowledges come, and how each in their own right can be enabled to contribute to our common future.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

FUNDING

This work was funded by Netherlands Organization for Scientific Research [Nederlandse Organisatie voor Wetenschappelijk Onderzoek], grant number 31399300, and DSM India.

NOTE

1. RespInnBio is the acronym for the project Responsible Innovation of Biogas.

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Turning Straw to Gold: Mobilising Symmetry in Responsible Research and Innovation

ANNAPURNA MAMIDIPUDI and NINA FRAHM

This article aims to reflect on the role of Science, Technology and Society (STS) research(ers) in co-constructing Responsible Research and Innovation (RRI) in the Global South. By reporting on RRI research in the Global South, here the Indo-Dutch NWO-MVI project on rice straw burning in Punjab, we make an argument for approaching RRI as a symmetric process of knowledge production mobilised by local actors and researchers alike. For STS researchers to responsibly engage with local innovation systems, their activities need to go beyond knowledge provision and towards facilitating the ownership and circulation of local meanings and means to responsibly innovate. Rather than understanding RRI as a fixed framework to govern innovation practices, this article reflects on RRI as an approach that combines research with intervention. We propose that following the principle of symmetry can turn RRI into a productive tool for the mobilisation of embedded local principles that can organise innovation systems in a responsible way. In particular, symmetry allows the re-location of meanings and practices of innovation as well as the re-negotiation of multiple notions of responsible governance.

Keywords: Responsible research and innovation, Global South, postcolonial STS, Epistemic Justice, sustainable agriculture and biogas

Introduction

The case for Responsible Research and Innovation (RRI) in the Global South seems straightforward: In order to align innovations with local needs and concerns, an

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Science, Technology & Society 25:2 (2020): 223–239
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820902964

inclusive governance framework is required which accommodates multiple actors upstream in the innovation process. After decades of critique of techno-scientific development agendas and persisting hegemonies generated through universalistic governance models, RRI figures as a promising approach to re-embed innovation in its place of emergence. Scholars in Science, Technology and Society (STS) have not only been central in foregrounding such participatory[1] approaches to the governance of science and technology but they also play a key role in researching the conditions of and propose tangible solutions for innovation systems to become more 'responsible'. Yet tasked increasingly by European institutions with the project to mobilise the RRI framework in the Global South, STS researchers are confronted with a major tension: How to navigate on the ground without repeating linear ideas of knowledge transfer from North to South, this time under the guise of *responsible innovation*? How to responsibly facilitate the emergence of local systems of *responsible innovation*?

In this essay, we[2] reflect on the tensions that arise for the STS researcher in mobilising RRI in the Global South. We posit that understanding and practicing RRI as a governance model that can easily be transferred from the desks of STS researchers and halls of European policymakers to local contexts may risk letting the fabled camel into the tent, which the STS scholar must confront. Two major tensions serve as a baseline for our reasoning: One along the North–South divide, the other among policy frameworks and STS theory. Our arguments are illustrated through a two-year research project on the 'Responsible Production of Biogas in India', which was funded by the Dutch research council Nederlandse Organisatie voor Wetenschappelijk Onderzoek through its Platform for Responsible Innovation (NWO-MVI),[3] and where one of us figured as a researcher.[4] Addressing research as one of the many practices of knowledge-making, our lens is turned to ourselves, the researchers—not only as analysts but also as actors among many others in finding responsible ways to innovate the recycling of rice straw in India. We claim that by mobilising a basic tenet of STS—the principle of *symmetry*—in knowledge production, we can facilitate the recognition, circulation and negotiation of plural epistemologies through which responsible innovation systems might emerge in local contexts.

To think and act symmetrically vis-á-vis diverse epistemologies provides fruitful ground for countering the hierarchisation of actors and knowledge-claims in processes of research. Such a reflection is particularly relevant where systems of innovation are characterised by stark cognitive inequality and vulnerabilities that determine livelihoods, as is the case for farmers in the region of Punjab and their struggle to find a solution for the environmental and social damages produced by rice straw burning in India. Through focusing on moments in the project where hierarchies—financial, social, cultural—that effect *epistemic justice* are negotiated, we illustrate how acting and thinking with *symmetry* can facilitate the attribution of innovation and its governance to their place of emergence.

The essay uses vignettes from the research process which act both as data and as moments that provoke us to reflect on the manifold inequalities and strong asymmetries that abound in this context. We show how such moments of reflection

were generative for mobilising *symmetry* in research practice, with which pre-constructed boundaries could be bridged. Before delving into the vignettes, we give a brief contextualisation of our reflections, which centre around the tension of mobilising RRI as a governance framework in the Global South, while keeping intact the core value of *symmetry* that characterises STS research. *Symmetry*, we propose, mediates the challenge of appending *responsible*—or any other prefix—to the word *innovation* that seeks to govern its direction and content, and makes RRI a worthwhile enterprise for responsible STS research.

Tensions in Mobilising RRI in the Global South

Discourses around responsibility in processes of innovation have a long trajectory in approaching the governance of science and technology in modern democratic societies, and are gaining renewed attention in our times (Lengwiler, 2008; Mody, 2016). In the face of the first accounts of the 'Limits to Growth', attention to questions of responsibility, particularly with regard to the effects of technological progress on eco-systems and the environment, triggered new conceptualisations of the relationship between technology and society (Bruntland Commission, 1987; Jonas, 1985; Meadows, Meadows, Randers, & Behrens, 1974). Social studies of science and technology evolving in parallel to such discourses identified how an increasing reliance on science and technology creates *risk societies*, which are characterised by *organised irresponsibility* (Beck, 1986, 1988), that is, lacking means to assign accountability for the consequences of industries and technologies on societies and their environments. The questionable capacity of scientists and engineers to govern themselves in a responsible way, and to be responsive to the societies they aim to serve, has since been subject to STS scholarship, critique and engagement (Bijker, 2010; Brown, 2009; Jasanoff, 2011; Sismondo, 2008).

In light of recent experiences with public resistance to the top-down introduction of emerging technologies into societies, such as genetically modified organisms or nanotechnologies, inclusive and participatory frameworks are gaining new currency in the governance of innovation (Chilvers & Kearnes, 2015; Owen, Macnaghten, & Stilgoe, 2012). Embedded in Anglo-American and European schools of thought, these frameworks are often developed in and for socio-technical systems of the Global North, and can be read as responses to broader critiques of a 'crisis' of science and technology in modern democracies (Brown, 2009; Law & Lin, 2017). Attempts to reform the relationship between participatory and democratic decision-making and cultures of self-governing science and technology are manifesting particularly in Europe through the framework of RRI. During the last decade, RRI has been gradually included in and further institutionalised by the European Union's (EU) Horizon 2020 Framework Programme[5] (De Saille, 2015), where it figures as a cross-cutting theme to better align European R&D with its heterogeneous publics.

Although definitions of RRI are still in flux, prominent attempts at synthesising instruments and concepts under the umbrella of RRI share the language of collective decision-making, early integration of stakeholders, anticipation of future

consequences and a more flexible system of governance. More often than not, it is presented as a set of principles, such as the EU's five elements of RRI (*public engagement, open access, gender, ethics, science education*), or Stilgoe, Owen, and Macnaghten's (2013) four dimensions of responsible innovation (*anticipation, inclusion, reflexivity, responsiveness*).

Whereas STS has consistently argued for a context- and culture-specific governance of science and technology, the policy rhetoric of RRI today reads as a 'one-size fits all' style of governance, with wide repercussions for the operationalisation of responsible innovation instruments and practices. Such a trajectory should not surprise the analyst, given the reliance on universal models of innovation and innovation governance in science, technology and innovation policy (Pfotenhauer & Jasanoff, 2017a). Further, as Eizagirre and colleagues note, '… the inclusionary or political eagerness represented through RRI must grapple with the strategic imperative of competitiveness and economic development' (Eizagirre, Rodríguez, & Ibarra, 2017, p. 20).

The divergence between RRI's constructivist framing in STS and RRI's mobilisation by policymakers and funding and research institutions confronts the STS researcher with a dilemma. Whereas STS has advanced the principle of *symmetry* in order to show how knowledge claims are always inherently contingent, and should not be hierarchised by the analyst in terms of true and false beliefs, it encounters the essentialist character of techno-scientific politics which rely on causal and deterministic explanations of knowledge-making (Gieryn, 1995; Stone, 1997), including what is considered to be the *responsible* production of science and technology. *Symmetry*, in the words of David Bloor, requires '(a)ll beliefs (…) to be explained in the same general way, regardless of how they are evaluated' (Bloor, 1976, p. 158). Such a methodological relativism does not inhibit the STS scholar from taking a normative stance vis-á-vis claims of knowledge and their consequences for society, but binds analysis to be open towards the manifold interpretations of the world around us, as well as ways for acting upon it with technological means (Bijker, 2003). This openness runs the risk of being closed down by the institutionalisation of RRI in terms of prescribed principles, which leave little room for culturally embedded ways of reasoning about and governing the development of science and technology (Jasanoff, 2005).

As the research project on 'Responsible Innovation in Biogas in India' laid bare, the challenge of navigating the politics of RRI on the ground is not only a theoretical one, and cannot be reduced to the intellectual sensitivities of STS alone. The marginal uptake of RRI language and practice beyond the EU indicates how RRI is still very much a European Agenda (Lavrijssen et al., 2017), which is difficult to mainstream within Europe itself, let alone beyond its borders (Davies & Horst, 2015). Federico Vasen, for example, criticises that while '(…) the RRI discourse is relevant to Latin America, (…) the tools and cases proposed do not fit with the main local concerns' (Vasen, 2017, p. 94). Concepts such as *Frugal* and *Grassroots Innovation* that emerge from scholarship in and are addressed towards the Global South largely remain outside the domain of RRI, even though they seem to address

a similar set of concerns (Bhaduri & Kumar, 2011).[6] That such *Epistemologies of the South* (De Sousa Santos, 2012) are not considered more substantially in discourses around RRI gives attempts of mobilising it in the Global South a post-colonial flavour, regardless of its opposite intention (Pandey, 2016).

Models of linear knowledge and technology transfer have enjoyed thorough critique from STS scholars and have often resulted in resourceful but ineffective policies with regard to so-called 'pro-poor' innovations (Thomas, Fressoli, & Becerra, 2012). For instance, the concept of *socio-technical resistance* captures how local communities often counter the hegemonic apparatus of innovation policies, which allows '(…) to generate a socio-material basis adequate to their view of the world or to prevent the stabilization of technological systems adverse to their visions' (Thomas, Becerra, & Garrido, 2017, p. 198). RRI's current operationalisation in policymaking and funding institutions does not favour such a resistance—in fact, it reduces participation to a *Machinery for Making Publics* that stabilise hegemonic narratives of modernist progress (Blok & Lemmens, 2015; Felt & Fochler, 2010; Leach, Scoones, & Wynne, 2005).

Sticking to the principle of *symmetry*, in contrast, requires that researchers carve out and confront these hegemonies. To remain symmetrical when mobilising RRI in the Global South, the STS researcher has to be reflexive in relation to both, governance *and* innovation: towards local cultures of (responsibly) governing processes of innovation as well as towards local understandings of (desirable) innovation itself. Pre-defined RRI principles, which are to be operationalised in local contexts by the STS researcher, also entail an a priori understanding of innovation and its rightful place in society. Where techno-scientific development agendas have worked as subtle forms of social engineering mediated through imperatives of progress (Visvanathan, 1997), RRI risks becoming yet another policy project subordinating local populations to 'right and wrong' modes of governance and visions of socio-technical change. These are the tensions we aim to address in the following pages, showing how the mobilisation of *symmetry* by the STS researcher can take RRI back to its constructivist roots, and turn it into a productive approach towards generating locally desirable as well as responsibly governed innovation.

Mobilising Symmetry: Five Vignettes from the Ground

… Between Social and Technical Domains

> *How can rice straw that is being burnt as waste by farmers in Punjab and causing environmental damage be converted to sustainable biogas that can benefit farmers?*
>
> —Project proposal to NWO-MVI, Responsible Production of Biogas in India, 2015

The answer to this question is innovation. In a meeting[7] attended by scientists and social science researchers on 'Nanotechnology for Development', a senior scientist[8]

working in an Indian subsidiary of a Dutch chemical technology company and heading its social innovation centre in India outlined a problem that his team could provide a solution for. Annually, farmers burn 17 million metric tons of rice straw in the Punjab region of India, causing air pollution that brings the nearby city of New Delhi almost to a standstill. The solution would be a pre-treatment technology that breaks down rice straw into biogas, turning waste into sustainable energy. The additional social ambition of the project was that biogas technology would then enter the circular economy of the farmer, instead of being siphoned away from the local community for commercial use driven by corporate interests. To achieve this, he touted the idea of a partnership between his team and STS scholars.

This was a sentiment that resonated with the Dutch NWO-MVI call for proposals of 2015–2017 which asked 'How do you bring about responsible innovations that enjoy broad societal consensus? How do you make better products and services?'. It posited that R&D that is tackled in a socially responsible manner would not hinder growth and opportunities in the market but can instead accelerate these—here RRI was claimed to be a 'tried and tested formula'.[9] Under this motto, the project for 'Responsible Production of Biogas in India' was taken up in partnership between the Corporate DSM-India and Maastricht University researchers, proposing a symmetric engagement with both the social *and* technical goals of the project.

… Between Science and Spirituality as Claims of Truth

> *We want to go on airplanes, and you want us to go back to gobar gas and bullock carts?*
>
> —Large farm owner, Krishi Vigyan Kendra, Punjab, 2016

On the prospects of biogas as solution to the rice straw burning problem, a large farm owner collaborating with the Krishi Vigyan Kendra (Agricultural Science Centre) in Punjab responded with some heat. His implicit assumption was that progress was achieved through moving forward with modern science and technology—technology thus was the prerogative of scientists, and the newer, the better. Biogas with its inner functioning laid bare in smelly dung pits in backyards. It did not make the cut against piped gas black boxed in red cylinders.

Biogas had been in use in rural India since 1900, through methods of composting that generated methane, as an alternative to coal. It was referred to as *gobar* gas or cowdung gas, a name that has stuck to it, to the present. During the Second World War, as by-product of nitrogen rich fertilisers, it acquired visibility as alternative cooking fuel in the appropriate technology movement of the 1970s (Raina & Chanakya, 2017). Yet the idea of being a poor man's technology came in its way, and the appellation of *gobar* gas acquired a pejorative aspect, as backward technology. While biofuels are currently perceived as the most promising option for clean fuel in Europe, requiring cutting-edge technology to break down lignocellulose-based inputs, to the Indian farmers themselves biogas speaks of a downmarket technology smelling of cow dung and the rural past.

Swinging to the other side, NGO leader Umendra Dutt, a farmer activist from the NGO Kheti Virasat Mission (Farming Heritage Mission), pointed to the negative effects of the displacement that modern technology had engendered. Foregrounding Green Revolution technology's negative aspects in farming in Punjab, he posited it as a destructive monster. Displacement of old ways of farming with new technological regimes in his experience inevitably caused disenfranchisement[10] of vulnerable farmers. In addition, fundamental cultural notions of good and bad were displaced. Talking in terms of value neutrality to technology is problematic for those who take a stand against the negative aspects of technology, he cautioned. Instead, he pleaded for spiritual notions of farming.

How can the researcher who seeks to be symmetrical adopt the framework of (responsible) innovation without a certain technological rationality being embraced? The very notions of what is conservative, or progressive, comes into question when traditional organic farmers, who seem to provide the most durable solution to the rice straw burning problem, do so using spiritual terms—those of *Dharti Maa*, Mother Earth, and their duty, or *dharam,* towards her.[11]

In resolving this dialectic between different claims of truth,[12] thinking symmetrically with RRI was hence better conceived not so much as value neutrality but as tolerance (at least for the duration of the conversation) of other actors' notions of good and bad, whether old (regressive/traditional) or new (progressive/modern), and regardless of where the actor's value system was exactly rooted and acquired. Such tolerance became essential if actors bearing different epistemic values, whether spiritual or modern-scientific, were to work together to solve problems as a responsible innovation system.

Framing care as a common concern for the future, symmetry was used to bridge the discursive distance between science and spirituality as ways of knowing. At the end of the two-year project, a key recommendation focused on the missing cultural perspectives in current debates around the problem of rice straw burning. It stressed the importance of learning from organic farmers who incorporated a culture of care and commitment to their land into their technical and social practices, despite economic vulnerability: *The unsung heroes of the problematics are in fact the organic farmers*.[13] Innovation and sustainability thus were not to be understood as fixed notions, packaged by the researchers and transferred to foreign places but rather as emergent from local contexts, and explicated as such.

… Between Linear Design and Implementation

> *How is the project different from the old linear model of design implementation, where the innovation is in the technical-design phase, and the job of social scientists is then of mechanistical implementation in society?*
>
> —Question from the NWO-MVI project reviewer, 2015

Framing a solution of biogas production to the problem of rice straw burning already in the design phase of the project created a design/implementation asymmetry.

Indeed, it was presumed that by using RRI as a framework, research projects would identify the ethical and societal aspects of technological innovations at an early stage so that these could be considered in the technical design process, reducing costs at a later implementation stage.[14] Given that stakeholders might be identified at a later stage in the project, how could their solutions be brought into play?

In response to this question, the researchers argued against a deterministic and for a constructivist account of responsibility in innovation. First, they recognised *interpretive flexibility*—that different groups attribute different meanings and interpretations to each technological artefact—in defining which problem is at stake in the Punjab case, and that innovative solutions on the ground could change problem definitions. Second, the researchers affirmed the capability to innovate solutions by those living with economic vulnerability. Poor but knowledgeable farmers were not to be conceived as passive consumers of innovation but as pro-active innovators (Mamidipudi & Bijker, 2018). Third, the researchers claimed, problem-solving is a back and forth process, rather than a moment in time and space—responsibly innovating socio-technical systems is always work in progress. The propensity of a system to keep problem definitions open became key to offset the effects of linear temporality between design and implementation.

Farmers' knowledge and innovations that researchers encountered during the course of the project were foregrounded in the final recommendations to the Indian state, breaking out of the linear design implementation logic the reviewer had cautioned against.[15] This was facilitated by the corporate partner DSM India, which brought to bear its not inconsiderable clout with the state, brokering a collaboration for the research team with a senior government official in the Ministry. His interest was to *turn rice straw to gold*—or, in this case, 2G ethanol—in order to comply with international agreements for bringing down greenhouse gas emissions and meet India's goal to bring down oil imports.

Running in parallel to the project period, to this end, an innovative policy move[16] in the area of biofuels was made. This entailed the moving of biofuels work from the Ministry of New and Renewable Energy (MNRE) to the Ministry of Petroleum and Natural Gas (MoPNG), with the intent of scaling biofuel production. This allowed capital rich and government-owned oil marketing companies to invest[17] in developing and adopting new 2G ethanol production technologies, with biogas as a by-product, rather than depend on traditional sources of credit capital that often are risk averse in relation to new technologies (Groves, Sankar, & Thomas, 2018).

Yet decision-makers from the Ministry were keen to incorporate farmers' knowledge into this policy, recognising that regardless of a preference for large-scale technological systems, in this context, small and marginal farmers had to be brought on board. Researchers from the RRI team were able to report on farmers' meetings, through demonstrating the links between the socio-technical systems that worked across energy and food security paradigms. As a result, the revival of state interest in the industrial production of biogas was informed by concerns of shared material and human resources between the two systems. Importantly, policymakers shifted from framing farmers as elements of a supply chain who would

implement top-down policy decisions, to taking their knowledge of long-term care and nurturing of environmental resources into consideration in the design of policy.

… Between Technological Regimes

Biogas from rice straw: Which biogas will win?
—PI of the project Wiebe Bijker on Constructing Worlds as an STS scholar, Valedictory Lecture at University of Maastricht, 2017

For most farmers, rather than being a problem, the burning of rice straw is a solution. Pushed into producing crops back to back in order to 'feed the nation',[18] the farming community had already moved once from organic farming practices to Green Revolution technologies in the latter half of the twentieth century. In managing the waste now being generated, for farmers, the collection of straw for conversion into biogas was an additional burden, and burning it was a solution. For the state, the ambitious national biofuel programme building on 2G ethanol was the solution, with the potential of using biogas as a substitute for natural gas, if rice straw could be efficiently collected, transported and eventually distributed after conversion to biogas.

Using constructivist STS as analytic, not just one but eight possible technological regimes for biogas were encountered in the course of the research. Each biogas was the outcome of the working of a different socio-technical system, made up of different social groups, technologies and institutions—one of them even a 'holy biogas', since cow dung had the best bacteria to break up rice straw. This went back to ideas of local sustainability and recycling where nothing is 'waste', at a time when cows were part of every (Hindu) household, treated as almost part of the family, and loved and prayed to. For the researcher not only to understand but also to act symmetrically upon them, there could be no a priori identification of what the problem and its best solution could be. More important, there also should not be losers: Every solution only seemed to displace vulnerability—to a new geography, a new group, or in time.[19]

In the example of rice straw burning being framed by policymakers as economic, it dislocated the problem onto cost of labour and inputs that could be solved by government subsidy. Here, the technological regime was that of the chemical pesticide and fertiliser intensive Green Revolution model. The social issues and politics of caste were dismissed in this problem definition, as were receding water tables, locking out a trajectory of more sustainable farming. The solution was framed as one of converting the waste rice straw into biofuels. As a result, the unsustainability of overproduction of food in Punjab was locked in, demanding long-term commitments from vulnerable farmers to continue to overproduce rice straw in order to regulate price volatility.[20] This solution tied together systems of national food security and energy security in a way that made both vulnerable (Bijker, Hommels, & Mesman, 2014).

In contrast, organic farmers argued that this problem could be solved only through dissenting with this technological regime as a whole. Their cultural

framework to describe their organic farming expertise posed a challenge for the organic technological regime in recruiting not only other farmers, and the public at large, but also policymakers and scientists who use the language of science and economics. A weakness of their narrative of cultural pride was that their interventions in organic farming were not understood as scientific, and were therefore not seen by others to offer credible solutions to the larger national problem of food and fuel security.

There was not a clear better solution, since each regime carried its own vulnerabilities. If one problem definition was not to win over the other, then the responsible solution to rice straw burning in Punjab needed to address concerns from both technological regimes. Such a symmetrical approach embedded responsibility within the negotiation of solutions between these diverse social groups.

When researchers mobilise RRI not just as frame of analysis but also as site of negotiation of diverse technological regimes, the work of coordinating across multiple interests, vulnerabilities and knowledge cultures is foregrounded. Knowledge must cross social, cultural and epistemic boundaries and barriers for responsibly innovating systems to work. It was when cultural knowledge of farmers was circulated as innovation, when corporates invested in societally relevant research (even when business cases did not yet exist) and when the state took on board issues of long-term sustainability in agriculture when planning for future energy security that the problem of rice straw burning began to be addressed. These, we propose, are outcomes of acting symmetrically with RRI in a context of diverse technological regimes—of treating all problem definitions, and all the possible biogases as equally relevant in defining conditions for responsible governance. Then, *symmetry* becomes an essential condition for the robust travel of knowledge across technological regimes.

… Between Dominant and Marginal Actors

What is your mobile number?
—Question from the audience to farmer at farmers meeting organised as part of the RRI project, Bahawalpur village, Punjab, 2016[21]

In a meeting of NGOs, famers' unions and organic farmers organised by the research team in the village of Bahawalpur, around hundred farmers met to discuss the problem of rice straw and to learn more about those who had found solutions other than burning. Initially skeptical about organic farmers' solutions' capability to scale, by the end of the day, the farmers were engaged in discussing the nuts and bolts of techniques that formed alternatives—mulching, composting, diversifying to name a few. Actors who had been marginalised as 'backwards'[22]—the organic, small- and medium-holder farmers who had taken to non-pesticide, non-fertiliser farming in the last decade—now moved at the centre of attention.

Rather than producing rice straw in excess and dealing with it as waste, organic farmers diversified crops, and excess biomass was recycled back into the land as

nutrient or as fodder for the livestock. In their perspective, land was to be valued, nurtured, nourished and replenished. They held themselves responsible for long-term and sustainable use of natural resource—their solution to the problem would be to generate less waste biomass. Following that lead, project researchers focused on organic farmers as possible innovators for the problem of rice straw burning. They were able to evidence knowledge circulation between the farmers; the final validation of that expertise explicated as the moment when members of the audience asked for a farmer's mobile number in order to know more. Farmers clearly were able to recognise innovations that other farmers had made to solve problems that they were facing. Researchers, through organising the meeting among farmers and being symmetrical about its participants' definition of problems and solutions, facilitated a space where the attribution of innovation came from farmers' peers, who had a fine awareness of practical knowledge in farming. This helped in the circulation of knowledge needed to unpick the complex conglomeration of problems—of resource, time, labour, propensities—that resulted in rice straw burning as a solution on the ground.

Proposing organic farming as a solution required that scholars keep interpretative flexibility open to the different meanings of innovation of the varied players. Not closing out vulnerable groups' meaning-making processes proved a challenge for the researchers. If the dominant narrative of solving the problem of waste through powerful corporate-driven innovation for the production of 2G ethanol were stabilised, it would turn farmers into suppliers in a potentially exploitative value chain. On the other hand, in keeping farmers' interpretation of innovation open, there was a danger that the narrative they constructed lost relevance for powerful actors such as the state, the corporate and the Dutch members of the valorisation committee.[23]

A strategic shift was made then by the researchers, back to the principle of *symmetry*: the propensity of innovations for doing good things and bad things in equal measure. By bringing in a common interest in long-term sustainability (the good)—and evidencing that the large-scale production of rice straw may not be sustainable both economically and environmentally (the bad)—an argument was made for innovation that could align the interests of farmers with other powerful social groups. This narrative shift enabled interoperability between the groups, to work with each other despite their different meanings of desirable innovation. The term *innovation* effectively became infrastructure for circulating knowledge between the various specialist groups, and the narrative of innovation that the researchers crafted built interoperability—of technologies, institutional scales and ontologies—that coordinated the working of the complex system.

The meeting was planned in conjunction with farmer groups, and was held in an organic farm, where local farmers provided hospitality to all the visitors and participants of the meeting. Their professions of religious sentiments that respected 'Mother Earth' were demonstrated in the plentiful bounty of the farm for all to see, and the farmers' role of providing food to guests as a spiritual act was validated and deliberately incorporated into the workshop proceedings. These were part of a common cultural framework of responsibility and ethical principles that bound all

Punjabi farmers, not just those practicing organic farming. It helped in moving the frame of innovation outside of modern techno-scientific vocabularies and closer to farmer vocabularies to describe their problems and solutions. Farmers were able to assert expertise, and others to reciprocate by validating it as such, turning the meeting into a hybrid learning environment. In such a space, the use of old and new technologies in knowledge circulation could become seamless both conceptually and in practice—whether sharing techniques of organic farming face-to-face, or through the use of mobile phones.

From being incommensurable as ways of knowing, such common practices form a basis for dialogue. RRI in this mode does not become a tool to merely govern innovations emerging from science and technology, but instead becomes generative of multiple sites of innovation across diverse forms of knowing. In doing so, research practice can create *symmetry* between the study and the governance of innovation.

Conclusion

In a children's fable, having helped the farmer's daughter spin straw into gold, resulting in her marrying the king, the evil imp Rumpelstiltskin demands in return her first-born child. There is a caution here, about the costs of turning straw to gold, particularly on the limits of fixed governance frameworks in dealing with stories of societal change. Principles such as *responsibility* should not be treated as decision procedures that spit out prescriptions, we propose them as organising principles that must aid both individual autonomy and co-ordination of collectives that is necessary for socio-technical change.

Where RRI approaches become a matter of recognising epistemology that determines life chances (Visvanathan, 2005), *participation* alone cannot serve as a principle for governing plural problem-solution definitions and their vulnerabilities. As Shiv Visvanathan has claimed, participation (or public engagement in policy language) is always oriented towards and guided by existing definitions of expert knowledge, in which the layperson's knowledge can only figure as a '… pot-pourri of practices, local ideas and raw material. There is no principle of equivalence' (p. 92). Instead of *participation*, we have shown, the farmers of Punjab embraced *epistemic justice*[24] in a symmetric act that recognised the organic farmer's solution as innovative.

Symmetry can hence strengthen perspectives that are productive for those wrestling with dominant actors' perspectives. This is in line with the shift in discussions from ethics to justice, where the problem shifts from one of powerful scientists exploiting vulnerable subjects to one of powerful institutions exploiting people. Science is no longer the problem (Reardon, 2013); it is the powerful institutional nexus between the corporate and technoscience that is exploitative. Southern NGOs that are battling the nexus through empowering publics already recognise this[25]: they found the framework of RRI that aligns knowledge governance within an idealised institution of social democracy only partially effective in their political battle, which

is to hold the State responsible for the governance of powerful institutional interests that work against poor farmers. Instead, by attributing innovative knowledge to farmers and strengthening their claim of innovation, actors in Punjab achieved recognition for farmer knowledge within policymaking. Symmetric engagement between the different knowledge practices of unequal actors was a necessary and a desirable political outcome—adding to the ideal of economic and social justice the condition of *epistemic justice*.

Mobilising *symmetry* in RRI research demands an enhanced reflexivity towards approaches for aligning innovation and society as tools to generate locally desirable outcomes. Models of innovation governance travel with imaginaries of what innovation and its purpose is, and which knowledge is needed in order to implement it (Pfotenhauer & Jasanoff, 2017b). Recognising that the social contexts of specialised knowledge production both enables and constrains the life world of actors is to recognise the limits of specialised expert knowledge, as being bounded by its specialist focus (Fisher et al., 2015). Acting symmetrically in this context means facilitating the circulation of plural epistemologies and investing in collective meaning-making processes. This, we want to argue, is responsible STS research and intervention.

The organising principle for collective meaning-making processes to be set free is an interplay between the researcher's and the actor's knowledge: Out of that interplay emerged an instance of *epistemic justice* in Punjab, which re-ordered power relationships against hegemonic ideals of progress and development. Then, there emerges a politics of identification—a politics of communal commitment and recognition—through which something foreign is made one's own. Theory does not go 'native', but serves as resource to solve a problem in a new context of use. In Punjab, it was local meanings of commitment and care which turned into a productive narrative for social groups in their quest to find a solution to rice straw burning, as evidenced in the idea of *virasat*, or inheritance, which does not push the problem and therefore its solution into the future. *Virasat* in this case, the inheritance embodied in the land and the knowledge of the community, has to be lived and enacted in the present if it is to be passed on. The local ownership of narratives allows for a collective ownership of problems and pathways to their solution.

If responsible innovations work well and stabilise in society, they embed collective principles that recruit different groups into arrangements that allow problem-solving, even problems that may come up in the future. Rather than techno-scientific imaginaries through which scientific truths travel in time, such arrangements become *socio-technical*, by recognising how—to paraphrase Sheila Jasanoff[26]—through the imaginative work of varied social actors, diverse narratives of collective good become enmeshed in performing and producing science and technology. Changing states of knowledge and societal values (Bellamy, 2016) in the socio-technical system can then be organised through a unifying narrative, rather than a universal truth. Such arrangements can make place for as well as deal with uncertainty, since anticipation of a different desired future does not preclude responsiveness in the present.

The moral of the story? Constructing collective narratives that include problem definitions and solutions of vulnerable stakeholders is important work. In the language of STS, it means to keep interpretative flexibility open—in the real world we engage with and in the scholarly work we produce. When mobilising RRI as an invitation for researchers to think and act on local problems, we need to ensure that our heuristics, tools and principles do not exclude the manifold epistemologies—both powerful and vulnerable—that must work together to make *innovation responsible*. As proposed in this essay, *symmetry* is a constructivist principle worth guiding our thoughts and actions.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

FUNDING

Annapurna Mamidipudi's work on this was funded by the Dutch NWO-MVI project for Responsible production of Biogas in India, 2015–2017. Nina Frahm's work on this was funded by the Innovation, Society, and Public Policy Research Grouo, Munich Center for Technology in Society, Technical University Munich.

NOTES

1. We are aware that participation is also extensively discussed in development studies (e.g., Cornwall, 2006) and design approaches (e.g., Chesbrough, 2003; von Hippel, 2005), but limit our analysis to perspectives on participation in STS scholarship.
2. Annapurna Mamidipudi was a researcher in this project, Nina Frahm is working on the limits and opportunities of RRI as a governance framework for transnational policymaking. The article is an outcome of conversations in the city of Berlin over the course of 2018, in which a shared concern around the mobilisation of RRI by STS research emerged.
3. See https://www.nwo-mvi.nl/project/responsible-production-biogas-india
4. Researchers in the project were Wiebe Bijker, Poonam Pandey, Annapurna Mamidipudi and Govert Valkenburg, with the support of research intern Amelie Riedesel for the fieldwork in Punjab, to whom we owe intellectual debts.
5. See https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation
6. We thank the reviewers for alerting us to the tendency of 'quick fixes' that most participatory policy frameworks share, whether labelled 'responsible, frugal, grassroots, or inclusive'. Our argument here is not to equate such frameworks, as they have evolved in very different areas of scholarship and address diverging levels and notions of participation and inclusion. Rather, we take the absence of Frugal and Grassroots Innovation frameworks as indicating a general lack of attention towards local knowledge and practices of innovation in RRI policy discourse.
7. Nano-Dev Workshop in Pune 28–29 March 2014.
8. Dr Murali Sastry, Nano-Dev Workshop in Pune 28–29 March 2014.
9. See https://www.nwo.nl/en/research-and-results/programmes/responsible<hig>+</hig>innovation/background
10. Fieldnotes of session 'Technology as Solution' Project Conference in Chandigarh, Punjab, 28–30 November 2016.

11. Fieldnotes Mamidipudi, Jaitu, Punjab April 2016.
12. In general, ideas of participation focus on scientific literacy (Giordano, 2018), given the difficulty in assessing other kinds of knowledge quality (Gregory, 2017).
13. Policy brief on missing cultural perspectives, Delhi/Maastricht, 1 December 2017. See http://www.maastrichtsts.nl/new-policy-brief-about-responsible-innovation-in-biogas-in-india/
14. See https://www.nwo.nl/en/research-and-results/programmes/responsible<hig>+</hig>innovation
15. Policy brief on missing cultural perspectives, Delhi/Maastricht, 1 December 2017. See http://www.maastrichtsts.nl/new-policy-brief-about-responsible-innovation-in-biogas-in-india/
16. See https://www.financialexpress.com/india-news/biofuels-related-work-taken-away-from-ministry-of-new-and-renewable-energy-given-to-oil-ministry/799078/
17. See https://www.downtoearth.org.in/news/energy/on-bio-fuels-in-india-61169
18. Farmers are known as *annadaata*, those who provide food, and those 'who feed the nation' (see http://csa-india.org).
19. Fieldnotes of session 'Technology as Solution' Project Conference in Chandigarh, Punjab, 28–30 November 2016.
20. For a discussion of bioeconomies and integration of the farmer into industrial value chains using the RRI framework, see (Groves et al., 2018).
21. Report, International Conference on Responsible Innovation and Sustainable Agriculture: The Problem of Rice Straw Burning in Punjab, Chandigarh, Punjab, 28–30 November 2016.
22. Report of fieldwork to villages Mehlawala, Bhatala and Jaitu in Punjab 2–5 July 2016.
23. All projects funded by the NWO-MVI programme were required to establish a valorisation panel with potential users of the knowledge produced by the project.
24. Here we draw from the notion of cognitive justice (Visvanathan, 2009): The right of people from diverse knowledge systems to their way of knowing as valid epistemology.
25. Fieldnotes of session 'Technology as Solution' Project Conference in Chandigarh, Punjab, 28–30 November 2016.
26. Jasanoff's actual phrase reads '… how, through the imaginative work of varied social actors, science and technology become enmeshed in performing and producing diverse visions of the collective good' (Jasanoff, 2015, p. 15).

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RRI's Commitment to Care and Vulnerability of Agrarian Systems: The 'Problem' of Rice Straw Burning in India

POONAM PANDEY

This paper employs RRI's mandate of 'commitment to care' to understand the 'problem' of rice straw burning in India and the possible ways of engaging with it. Straw burning is often framed as a linear technology or policy deficit 'problem' in need of an immediate and quick fix. Interventions and solutions emerging from such framings have so far remained ineffective. The 'commitment to care' approach enables us to situate the current practices of straw burning in a complex web of relationalities, dependencies, vulnerabilities, and affect. By doing so, the 'problem' of straw burning is rearticulated and redefined as a cumulative effect of multiple interventions, transformations, and contradictions that led to the shaping of modern agricultural systems in India. This re-articulation demands for a rethinking of engagement, remedies and responsibilities in ways that move beyond the individualization of blame and action.

Keywords: Agriculture, responsible research and innovation, vulnerability, commitment to care, straw burning

The burning of rice straw by farmers in the northern states of India in the months of October and November has emerged as a serious concern over the past few years. The severe detrimental impacts of agri-residue burning on air quality and

Acknowledgement: My special thanks to Shri Umendra Dutt from Kheti Virasat Mission (KVM), Jaitu, Punjab. His views on civilisational crisis in agriculture in Punjab have been extremely helpful in shaping my understanding of the field. I greatly acknowledge the constructive comments received from two anonymous reviewers.

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Science, Technology & Society 25:2 (2020): 240–255
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820902965

health of people in the nearby states including the capital city of Delhi has received wider coverage in national as well as international media (Kazmin & Singh, 2017; Mukerjee, 2016). Multiple solutions have been proposed and implemented. These range from strict legal action in the form of fines and jail time to technological interventions for straw removal and conversion to bioenergy (Berry & Sagi, 2017; Mukerjee, 2016). Despite the wide range of solutions offered over the past few years, the practice of straw burning still continues and has been increasingly adopted by farmers in different regions all over the country. Angry residents are often shown in the news clips complaining about their plight and asking why farmers are not stopping this practice, why farmers are being inconsiderate and uncaring towards people's health and why they are acting as irresponsible.

In this article, we will focus on the practice of straw burning and many questions around it that remain hidden under the narratives of success of techno-economic paradigm such as agricultural modernisation, by taking it to the point of its enactment—the farmer's field. The discussions and questions from the farmer's field are then situated in the scholarly debates around modern agriculture, in order to facilitate a dialogue between the experiences of actors and analysts. In doing so, we employ the plea for 'commitment to care' invoked through the scholarship on Responsible Research and Innovation (RRI) as a conceptual, analytical and empirical tool. The 'commitment to care' approach enables us to unpack not just the current practices (such as straw burning) but also the significance of these practices that often gets hidden by the 'dominant, successful forms of techno-scientific mobilization' (de la Bellacasa, 2015, p. 2). The situating of farmers' practices with the political economy of modern agriculture shows that straw burning is actually one of the unintended consequence of the successful implementation of Green Revolution technologies, left unanticipated and 'uncared' for while developing these innovations. From an RRI point of view, it raises questions of how far should anticipation and reflection go for the governance of technologies that are declared 'successful' during their introduction. We would argue that the 'commitment to care' as an engaged, continuous and practice-oriented approach becomes extremely important for RRI. In cases, such as this, the focus should lie not only on the introduction of a new technology into a system but rather also on subsequent, interconnected, multiple other changes in the entire sociotechnical ensemble of agricultural systems that made the technology work. But, also eventually, led to multiple vulnerabilities resulting in this unanticipated impact.

Our approach to critically engage with modern (GR) agriculture in relation to the practice of straw burning is not an attempt to create a dichotomy between the 'good' of traditional agriculture and the 'bad' of modern agriculture. Traditional agricultural societies in India had their own vulnerabilities as a result of over-reliance on nature (Gupta, 2005) and social order around power structures and hierarchies of caste, class and religion. Modern agriculture, in many ways, disrupted this with the hope of progressive reorganisation. However, it is the inability of modern agriculture to re-stabilise and improve rural life that resulted in new vulnerabilities and forms the core of our analysis.

As we will discuss in detail in the following sections, the 'problem' of straw burning is a cumulative effect of multiple vulnerabilities that systemically influence the practice of agriculture. We will look at the problems that lead to the decision to burn straw and the solutions that farmers deem suitable for it. Entangled in the problems and solutions for straw burning are different ontologies of agriculture and the ways in which it is considered to be 'cared' for. Although our fieldwork and farmers' dialogue meeting had a diverse group of farmers (described in detail in following section), for this study they could be broadly classified as those who burn the straw and those who do not. There were excellent examples in our fieldwork where individual farmers have adopted practices of in-situ straw management and organic farming. However, these are very recent and marginal trends in Punjab and Haryana where majority of farmers resort to burning of residual straw. This article is about the farmers who burn the straw.

Why Do We Care?

This article is an outcome of a two-year NWO-funded project Responsible Innovation of Biogas (RespInnBio) where a team of Dutch and Indian university researchers initially started a collaboration with the R&D division of an industry to work on developing biogas from agricultural residue. The plan was to engage with multiple stakeholders. Scientists working on different technologies, multiple government departments who have a role to play in developing supportive policies for bioenergy, industry and local entrepreneurs who would develop biogas and a sustainable business model for it and farmers who are the main agent for the production and supply of raw material or feedstock for the biogas plants. RRI demands a 'commitment to care for the future through responsive stewardship of science and technology in the present' (Owen et al., 2013, p. 36). This means that as researchers working on the project 'RespInnBio' in India, we need to commit to care for the futures which our project might help in shaping in multiple ways. For RRI, it generally means engaging with future (un)intended consequences of technology through anticipation, reflection, inclusion and responsiveness (Owen et al., 2013). A 'commitment to care' rather than predict and control the future in RRI points towards the acknowledgement of vulnerability of the technological cultures we live in, defined by uncertainty, ambiguity and fluidity (Bijker, 2006; Hommels, Mesman, & Bijker, 2014). As a result, requiring care as a response to vulnerabilities would entail an ethico-political obligation to be attentive to the most vulnerable and marginalised (de la Bellacasa, 2011). In order 'to care', RRI has to take local vulnerabilities and needs into account (Di Giulio, Groves, Monteiro, & Taddei, 2016) and pay attention to processes of exclusion and dominance that render innovations useless for them. Thus, without engaging with the vulnerabilities of agricultural systems and farmers who practice straw burning, RespInnBio seemed to be a far-fetched preposition.

Understanding the problem of straw burning by engaging with vulnerabilities of agricultural systems through RRI's 'commitment to care' would mean paying

attention to a diversity of relationalities between humans and non-humans such as soil (de la Bellacasa, 2015), micro-organisms (Schrader, 2015), machines, livestock and knowledge systems. Caring for these relationships is not only essential for the sustenance of agricultural systems but is also crucial to engage with the issue of straw burning. A care approach to vulnerabilities encourages a rethinking of these relationalities beyond the economic, technocratic and productionist paradigms (de la Bellacasa, 2015). For RRI, this emphasises paying attention to the social roles of agriculture (Thompson, 1986) along with its economic roles and culture of agriculture along with its science.

The Site of 'Caring'

Care is a politically charged practice that requires a continuous practical engagement and everyday material doing (de la Bellacasa, 2011). As an interventionist approach, 'commitment to care' is thus an open invitation for RRI practitioners to play an active and engaged role in collectively shaping the world and things they study and to be accountable to their becoming (Martin, Myers, & Viseu, 2015). For our two-year RRI project, engaging with farmers was not the primary activity, rather it was one among the many meetings that we had to carry out in a very limited span of time. Over the course of next one year and multiple interviews with different actors, it became clear that along with many technological, supply chain and market challenges, the burning of straw by the farmers is one of the biggest challenge for RespInnBio. No one we interviewed seems to have a clear and comprehensive idea, besides few wild guesses, about why do the farmers burn the straw even when they are warned of punitive and legal action.

Despite being very aware of the limitation of resources and time we had, it was decided that we should jump the wagon from thinking about how to develop a responsible industrial biogas to care about farmers' vulnerabilities. The site and mode of engagement, thus, becomes crucial. The biggest challenge in front of us as 'outsiders' in a rural setting was to meet farmers who were burning their straw. This challenge was amplified multiple times because of the blame, criticism and ridicule for the farmers circulating through media reports. Before arriving at the format of farmers' day event, we experimented with a number of other approaches to understand farmers' perspective. First, through the connection of the local non-governmental organisation Kheti Virasat Mission (KVM), we interviewed farmers who were using family-based biogas plants and doing in-situ management of straw through mulching. We got a second-hand understanding of farmers who burned the straw from the narrative of farmers who did not. As a next stop, we got in touch with a local agriculture science centre (Krishi Vigyan Kendra [KVK])[1] in Punjab, which is a government agriculture extension unit, to organise a meeting with the local farmers. This meeting consisted of a mixed group of twenty farmers (all male) who met with us in the presence of local government authority in the KVK conference room. Unfortunately, due to their one-to-one connection with the local authorities, most farmers shied away from openly discussing the reasons for choosing burning

as a method of straw management. The language of communication, where our questions in English were translated by the KVK officer into Punjabi and vice versa also became a major impediment in free exchange of ideas and a lot of information got mixed-up and lost in subsequent simplifications and translations made by the officer. By the end of the meeting, we were really not sure if it was the response of the farmer or the KVK officer. However, this exercise made us aware that besides the challenge of managing excess amounts of straw, farmers were extremely worried and concerned about the air pollution in Delhi and urban citizens' demand of accountability from them. Thus, as a third attempt, we asked KVM director to invite farmers who burn the straw along with those who do not as a part of a three-day seminar where scientists, social scientists, NGOs and local entrepreneurs would gather to discuss the issues of straw burning in an informal, open format. To this, he laughingly said 'farmers are not going to come to a seminar and that too in a fancy hotel'. What he was implying was that both the format and the space are not comfortable for farmers to talk about agriculture and its challenges openly. And it is only by organising a farmers' dialogue in a farmer's field can we get a better picture of what they think. For a free flow of ideas and discussion, farmers had to outnumber others[2] and the medium of communication has to be a local language that could be translated in English in hushed tones without interrupting the flow of discussion. Utmost care has to be taken to not individualise those who burn the straw in order to enable them to speak openly about their vulnerabilities and challenges. These considerations resulted in the farmers' dialogue format where more than 100 farmers gathered for a whole day of discussion. The event took place in a section of an organic farmer's field, which was actively chosen to demonstrate the potential of this farming method in engaging with the problem of straw burning. The food served during the event was also organically produced in the same farm and locally prepared.

The event was attended by farmers from Punjab and Haryana along with scientists, social scientists, NGOs and one biogas entrepreneur. Most of the farmers were medium landholders along with few having large and few with small landholdings. All the farmers were between the age group of 20–70 years. There was just one woman farmer who attended the event with her husband. The number of those who burn and those who do not burn the straw was roughly equal. However, those who do not burn the straw were not always organic farmers. Which means, despite practicing chemical farming many farmers reported that they do not burn the straw anymore.[3] After a few rounds of informal introductions about who everyone is and what they do, the event gradually transformed into a dialogue between those who burn the straw as a result of multiple vulnerabilities and those who are experimenting with different ways of practicing agriculture without burning the straw (including the organic farmers). Towards the mid of the day, farmers were openly discussing their challenges with a relative ease and exchanging ideas, practices and even phone numbers for a follow-up. There were few who reported that they had tried multiple alternative methods of straw management and have returned back to straw burning because the alternative methods had resulted in damage to their crops in the form

of diseases or low yield. There was hardly any instance where the modernisation of agriculture and the relational transformation of farming and farmer's life was not discussed. The problems of modernisation of agriculture were clearly apparent, but so were the challenges of reverting back to traditional methods.

The rest of the article will focus on the discussion of multiple vulnerabilities that impact farmers' decision to burn the straw.

Vulnerability Due to Scarcity of Time

One of the reasons that farmers gave for burning of straw was that there is a very small time window between the harvesting of paddy and sowing of wheat where farmers have to act fast and clear the fields as soon as possible in order to aim for the desired returns. According to majority of farmers in the meeting, burning the leftover straw on the field thus becomes the easiest, cheapest and most accessible way of getting rid of what they consider as 'waste', as their gaze is set on the next crop cycle. Farmers discussed the disconnect of natural means of rejuvenating the soil and its replacement with technological means which are much faster, the replacement of farm animals who could consume straw with machines and the lack of time with farmers to 'care' about straw. This altogether contributed to a culture of haste where time becomes the most valuable entity and vulnerability of losing time causes them to burn the straw. Majority of times, discussions around straw burning pay little attention to the processes through which this culture of haste has become a central feature of agriculture in Punjab and Haryana.

In 1985, the Government of Punjab appointed an expert committee to look at the problems of agriculture in Punjab (Jodhka, 2006). The Johl Committee report 'expressed concerns about the stagnation of productivity level and deterioration of environment due to the cropping pattern dominated by paddy wheat rotation' (Jodhka, 2006, p. 1532). The operation of paddy–wheat rotation in a continuous, mechanised fashion to draw maximum output points towards the deficiency of time engineered in modern agricultural systems that eventually leads to burning of straw. The culture of haste leaves little consideration for things, such as environmental pollution by straw burning, that do not call for immediate concern (de la Bellacasa, 2015; Nowotny, 1992; Wajcman, 2008).

The history of modernity could be read as a series of technological innovations that have resulted in ever-increasing time compression and independence of social relations of time from space and the body (Virilio, 1995; Wajcman, 2008). The removal of leisure time and leisure activities through either regulations or incentivisation deteriorated the sociocultural activities of labourers and workers in an industrial setting (Adam, 1995; Harvey, 1976). Many technological interventions in agriculture such as irrigation technologies and short life cycle varieties aim to increase productivity per unit time. Growing more crops per year and the promise of more income is an incentivising mechanism through which agriculture could be set in the commercial mode. However, this logic of productivity and yield-oriented

strategies of modern agriculture have worked against the local agricultural practices. Vasavi (1994), while discussing agricultural practices in Karnataka, argues that unlike the focus of modern agriculture on linearity and uniformity, traditional practices of agriculture indicate an elaborately constructed complex based on careful consideration of appropriateness, local context and accommodation for change. The natural means of preparing fields for next sowing season requires periods of breaks from agriculture and leaving the land fallow for rejuvenation for a certain duration of time. The leisure time and sociocultural activities in agricultural societies are neatly fitted during these periods of breaks from agriculture. These activities would range from engaging in different festivals to marriages of children (Vasavi, 1994). The stress of working with uncertainty and unpredictability of nature is taken off during this period of sociocultural engagement and farmers' rejuvenate along with the land for a new season of agricultural activities.

There were no discussions of festivals, songs or social celebrations in agriculture in the farmers' dialogue. In the case of Punjab and few other northern states, the technological intervention and incentives of more and more production and economic returns have set up a crop rotation cycle where there is no more a possibility of leaving the land fallow or taking a break from farming.

Vulnerability from Technological Treadmill

Farmers discussed how after the successful incorporation of combine harvesters in the farming practices the incidences of straw burning have increased. The use of combine harvester has completely transformed the agriculture and harvesting in Punjab and Haryana (Jodhka, 2012). It replaced labour, farm animals and threshers to decrease the cost and time of cultivation (Rahman, 2015). The combine harvester itself is a very expensive piece of farm machinery that required farmers to look for government subsidies, agricultural loans and informal credits.

Yet many of the farmers in the farmers' dialogue event demanded for technological solutions to the problem of straw burning. The demand for newer technology has become a pattern in the practice of modern agriculture, especially in regions of northern India (Kumar, 2016), to the extent that it has become an indirect measure of 'care' from the government and scientific agencies. A professor working on agricultural technologies in Punjab mentioned that 'it is a general belief among farmers that more technological inputs would invariably lead to more produce and output' (personal communication, 28 July 2016). The trust on technology has resulted in over-mechanisation as one of the leading cause of rising costs of production, especially in Punjab (Jodhka, 2012; Singh, 2000). The state has highest number of Tube wells, tractors and combine harvesters (Singh, 2000). The over-mechanisation often leads to low-input use efficiency (Singh, 2000).

The Happy Seeder was discussed by the farmers as the next 'it' technology for the problem of straw burning (Sidhu et al., 2015; Singh, Kang, Kaur, & Goel, 2013). Few farmers from Haryana suggested that their whole village has been using Happy Seeder and it has proved to be a very useful technology in relation to the

issue of straw burning. To this, many farmers responded that Happy Seeder has its own problems. First, it is very expensive and runs on diesel. To bring it to common use, it is essential that the government either provides subsidies on the machine as well as diesel or it makes the machine available through policy initiatives involving KVKs. Second, as the Happy Seeder puts the straw back to the soil, there are issues of water retention causing salinity of the soil as well as development of fungal diseases. Third, in order to use the Happy Seeder for sowing, the straw needs to be evenly distributed in the field; this again demands more technologies or labour. Further additional innovations and technological add-ons are needed to solve the problems that Happy Seeder creates. Straw Management System (SMS) is one such machine that could do the job of distributing all the straw evenly in the field.

The anticipated, unending demand for new machinery puts farmers on a technological treadmill that constantly contributes to distress related to acquiring resources in the form of either subsidies and loans or more cash. The increasing cost of production has also contributed to decrease in the number of cultivators. As a result, many small and marginal farmers are unable to bear the cost of inputs, and they are forced to quit cultivation themselves and lease their land to medium farmers who have the desired resources (Singh, 2000).

Vulnerability from Market-centric Approach to Farming

The current farming practices in Punjab and Haryana are completely geared to the market of paddy and wheat. The government support policies that once aimed at 'caring' for farmers through market mechanisms have created severe distresses in the form of livelihood choices and natural resource depletion. Farmers questioned the suitability of growing paddy in Punjab. One of the farmer said

> Farmers have many other problems to deal with than straw burning. Most of the people present here are not consuming rice but sowing it. In the attempt to produce more and more we have stopped taking the requirement, need and quality of the field into account. How did we end up doing rice cultivation when we do not even consume it? I think we got brought into the promise of Green Revolution and destroyed our farming. (Farmer, personal communication, 28 November 2016)

Farmers explained that they are aware that the current agricultural markets are exploitative towards producers and puts huge pressure on the resources as well as the farmers themselves. Despite this awareness, it is extremely difficult for individual farmers to move out of this system without incurring huge losses which sometimes amount to debts and loosing lives (Farmers' Dialogue, 28 November 2016). One farmer also questioned the ever-deteriorating condition of farmers' vis-à-vis other agents who earn their livelihoods by promoting GR agriculture. He said 'there are scientists, technology companies, seed, fertilisers and farm equipment sellers, all

of them have reached a better place by working with agriculture while it is just us farmers and our conditions that are continuously deteriorating in this model'.

As part of the GR package, many market policies were introduced by the government. This included setting up Minimum Support Price (MSP) and government procurement centres for major GR crops such as rice and wheat. These initiatives were brought in place to prevent exploitation of farmers, especially the small landholders, from local middle man and moneylenders (Jodhka, 2006). Multiple credit and loan mechanisms and farm subsidies were set up for normalising the input costs of machinery, fertilisers and pesticides, electricity and new seeds (Gill, 2010; Gill & Singh, 2006). These policies have proven to be very helpful and supportive for the farmers during the early years of Green Revolution. However, as Jodhka (2006) points out, many factors led to the decline of effectiveness of these support systems, post-economic reforms in the country in the 1990s. These include lethargy of procurement agencies in procuring produce directly from farmers, lack of proper revision for support price from central government, dominance of local middle men, moneylenders and private players in the market space and lack of proper storage facility (Jodhka, 2006). As a result, the situation of increasing expenditure in agriculture and decreasing output prevailed and had put majority of farmers in a state of perpetual debt.[4]

The neglect of local environmental conditions and over-exploitation of resources such as groundwater for irrigation were reported as another stress factors by farmers. Some farmers explained that the market orientation of farming also led to extinction of many traditional varieties of crops that were suitable to be grown in these regions and would provide support to the agricultural ecosystems. Government has also initiated an MSP and support programme for lentils in Punjab. Farmers in our meeting told that due to their dependence on local traders for credit, they are invariably tied to them for selling their produce. Local traders do not seem too enthusiastic to procure anything other than rice and wheat in good price. Government attempts to regulate the market have proven inefficient so far, further adding to the power of private traders. As a result, all efforts for diversification of agriculture, including lentils, have failed.

Vulnerability from 'Deskilling' of Farmers

The practice of straw burning, as many farmers recall from their memory, was first supported and promoted by KVKs and agricultural extension scientists. Farmers gave multiple explanations in support of straw burning ranging from 'they burn the straw based on scientific knowledge that the potash from the ashes enriches the soils' to 'similar age-old practices of traditional agriculture in north-eastern states of India'.[5] Farmers expressed their dependence on state authorities not only for the delivery of technology but also for the appropriate knowledge that needs to be used to effectively manage straw and prevent burning. In the absence of the 'right' solution proposed by KVKs, farmers explained, they are left with no choices but to burn.

Agriculture is a skill-based means for sustaining livelihoods. There are multiple factors, including experience, education, sociocultural beliefs, proximity and access to resources and networks that contribute to learning and development of agro-ecological skills (Stone, 2007; Vasavi, 2009). This systematic and long-term engagement through observation, discussion and participation in each other's activities eventually gets institutionalised and ingrained in sociocultural practices (Brodt, 2001; Fitzgerald, 1993; Kumbamu & Stone, 2007). Stone (2007, p. 73) argues that farming is a 'performance that changes in response to changing technologies, pest, climate, seeds and agricultural policies', which means that agricultural skilling is not static but a continuous and ongoing process of environmental and social learning (Stone, 2007). This entails that unlike industrial set-up, introduction of mechanisation is not just automation of farm tasks, but rather, a disruption of this learning mechanism and systemic degradation of a farmer's ability to perform, choose and innovate (Stone, 2007).

In the GR model, farmers' knowledge was considered outdated and unfounded on scientific facts (Ellis & Biggs, 2001; Vasavi, 1994). Knowledge and expertise coming from 'trained experts' held more value and farmers grew increasingly disregardful and hesitant to use their own time-tested knowledge and methods (Vasavi, 1994, p. 294). Along with this, different mechanisms of incentivising and rewarding 'good' farmers as those who are good followers and implementers of expert advice rather than innovators and disregarding dissenting farmers further contributed to knowledge de-skilling in terms of trusting, retaining and practicing their own knowledge (Kumar, 2016; Vasavi, 1994).

In the farmers' dialogue, despite the common acceptance that straw burning is hazardous, there was an observable distrust on other forms of in-situ straw management such as mulching. Farmers reported many challenges of executing alternative ways of straw management including lack of time and resources and damages caused by waterlogging and diseases. Although, those who burn the straw were appreciative of those who do not, there was an apparent discomfort and hesitation in adopting their methods. For every farmer who suggested novel ways of managing straw other than burning, there was rigorous questioning from others which culminated in exchange of phone numbers if the proponent was able to establish some trust by justifying his method.

Vulnerability and Deteriorating Social Institutions

Punjab and Haryana are often known as the land of 'progressive agriculturists' (Jodhka, 2006, p. 1531). To a large extent, along with technological and institutional innovations, credit for the success of GR is given to the enterprising farmers who took pride in their agriculture, identified with their land and made farming as a matter of dignity and honour (Gupta, 2005; Jodhka, 2006). Preston and Wickson (2016, p. 50) argue that 'agricultural practices significantly shape both community and personal identity, implicitly expressing deeply held moral convictions'. The

introduction of technological and economic changes might result in disruption of these practices which constitute identity and agency (Di Giulio et al., 2016). Ideally, these disruption must result in new alliances and mechanisms to re-constitute identity and community. However, in case of agriculture in Punjab and Haryana, the process of re-constitution has left gaps and vulnerabilities that does not sustain and support rural community and rural way of life. The loss of identity, moral authority, community and trust is the subtext of the phenomenon of rice straw burning that often goes unrecognised. The government's decision to take legal action against farmers burning straw aggravates this challenge further.

All the farmers we interviewed were strictly against the criminalisation of farmers for straw burning. Farmers said that looking at the distress through which agriculture is going through all over the country, there is a dire need to appreciate and support farming and agriculture rather than blaming farmers for the problems of pollution. The leader of the Kisan union said that

> Farmers are very sincere about the problems caused by straw burning and desperately trying to find a solution for it. But they alone cannot do anything. Farmers are being criminalised and put to jail. Is this the way the government and the society is rewarding the people who have taken up the responsibility of ensuring the food security of the nation. (General Secretary of Kisan Union, Mansa, Punjab)

Farmers expressed their deep concerns towards the disinterest of younger generations and women in agriculture and the future of agriculture. Study has shown that this disinterest is registered across the caste and class spectrum (Jodhka, 2012). For the youngsters of the Dalit communities, agriculture symbolises the power and patronage by the locally dominant classes. Thus, they often try to dissociate from traditional agrarian systems for political reasons (Jodhka, 2006).

Several farmers reported that all the young people who get college education often consider agriculture as a demeaning job. The impact of modern education on downgrading of farming as an occupation and devaluing of farming skills of rural youth have been reported in literature (Sharma, 2007; White, 2012). The impact of economic development from agricultural growth in the GR period led to focus of rural population towards modern education (Gill, 1988, 2005). Rather than returning back to village and practice agriculture, many college-educated youngsters from dominant agricultural castes preferred to stay in the city waiting for the appropriate jobs (Jeffrey, 2010). Agriculture and rural life no more appears attractive and neither can they identify with it as an all-encompassing way of life and identity (Lindberg, 2005 in Jodhka [2006]). The disinterest of the younger generations in farming also results in absentee landlords and the culture of renting farmlands contributing to rising rent prices and over-exploitation of agriculture to combat them (Gill, 2005). The vulnerability for burning straw is increased manifolds when the elderly landlords are unable to do manual tasks and the tenants save labour costs to recover rent prices. One elderly farmer responded in a desperate manner saying

> we are quite helpless in the present situation! Who doesn't know that burning of the straw is not good but we do not have any choices. We are old and incapable of harvesting ourselves and our youngsters are not interested in doing the farming job. They want to move to the cities and even to foreign countries. The government can find a solution if they want, but they are also looking away. (Farmer, Bahawalpur, Punjab)

A similar response was observed when discussions around agriculture and women in relation to changing gender dynamics and disconnect of agriculture and nutrition were initiated. This shift is majorly observed among women of dominant agricultural castes. One farmer retorted that

> Our women do not have any interest in farming these days. They are educated and do not want to get soiled. They cannot tell which farm we have and would not know the basic farming terminologies. They do not visit the farm at all, not even to bring us lunch, which was earlier the case. (Farmer, Bhatinda, Punjab)

The hierarchical organisation of agriculture in rural settings in India based on distinctions of caste, class and gender are very well established (Gupta, 2005; Jodhka, 2012; Vasavi, 2009). However, in that highly hierarchal and inequitable society, agricultural practices provided a common and shared space where cultural prescriptions and social transactions were negotiated (Vasavi, 2009, 1994). The integration of agriculture into the market economy has led to reordering of these cultural norms with double negative effects (Gill, 2005). Although the social customs of caste, dowry and patrilineal land rights are still largely retained, the integration of agriculture to market economy has led to individualisation and deterioration of community support in times of crisis (Padhi, 2009; Shiva, 1991; Vasavi, 2009). The increased burdens of risk resulting from individualisation, lack of adequate support from institution and state, and vacuum created by deterioration of traditional social institutions results in vulnerabilities that contribute to decisions of rice straw burning.

Concluding Discussion

The issue of straw burning is often presented as a singular, disconnected 'problem' in need of an immediate and quick fix. There is an apparent linearity in the ways straw burning is framed as a technology or policy problem, leading to solutions that remain ineffective and inefficient. This article, by engaging with the perspectives of farmers who burn the straw, re-articulates the 'problem' of straw burning as an issue deeply embedded and intricately intertwined in the political economy of contemporary agriculture in India. The re-presentation and re-articultation of the 'problem' of straw burning as a cumulative effect of multiple vulnerabilities of practicing modern agriculture serves two purposes from a 'commitment to care' perspective. First, it reasserts the ethico-political obligation (de la Bellacasa,

2011) of RRI practitioners towards being attentive to the processes of naming and representation that result in the becoming of knowledge and things. In the present case, the re articulation of straw burning as a collective effect of multiple vulnerabilities highlights the complex relationalities and responsibilities that get hidden in the dominant and linear narratives of success of techno-economic paradigms. The 'commitment to care' also means not just being sympathetic and concerned about neglected things/issues/knowledges but also making an active effort to bring the neglected to the fore. It is well known that agricultural practices are hybrids of traditional and modern knowledge. However, the process of hybridisation is often uneven resulting in gaps and voids that lead to multiple vulnerabilities. This article re-articulates these vulnerabilities in relation to the issue of straw burning in order to make them visible and accountable for decision-makers. The article articulates different vulnerabilities resulting from markets oriented to global consumers rather than local producers, technological treadmill, productionist cycles of rice–wheat rotation, the challenges posed by deskilling of farmers, and the deterioration of sociocultural institutions of community, identity, and local knowledge, that eventually results in the decision to burn the straw.

Second, by situating straw burning in the broader political economy of modern agriculture, a 'commitment to care' enables demands for re-orienting response and responsibility for the 'problem' of straw burning. Reardon, Metcalf, Kenney, and Barad (2015) argue that sometimes it is the imposition of social conventions from the outside, which, despite the ability of vulnerable population to be responsive, limits their actions. 'To care' in such situations would be to look reflexively on the solutions provided to the vulnerable communities and the problems with their articulation that makes them unavailable, unhelpful or inaccessible for vulnerable communities. A focus on the vulnerabilities that farmers encounter in order to access different solutions is a fruitful way of engaging with the question of why they cannot stop this practice. This reflexively opens up the possibilities of intervention and change. For example, when a local entrepreneur started a business on converting rice straw to biogas to solve the problem of straw burning, he did not receive much support from the farmers because availability of fuel for domestic use was not their problem. Once the entrepreneur refocused and re-defined his business in relation to improving soil health by providing organic manure, his venture was acknowledged by farmers as helpful and they started extending their support to his initiative.

Care as practice also draws attention to ethico-political questions in relation to solutions/responses in the context of the problem of straw burning. These include looking critically at 'who cares for whom and what forms of care are prioritised at the expense of others' (de la Bellacasa, 2015, p. 18). A 'commitment of care' in relation to response would mean cultivating practices of continuous engagement-based, context-specific response in place of codified, disengaged and standardised solutions (Barad, 2007; Reardon et al., 2015). The response in the form of legal action and criminal charges against individual farmers found guilty of setting their fields on fire is an example of control centric, codified and disengaged approach.

Not only it disregards multiple vulnerabilities that led to the decision of straw burning by farmers, it also ignores multiple factors that contribute to building of pollution levels and deteriorating air quality in Delhi. By being disengaged to the producers and the causes of production of the problem, legal ban on straw burning became a solution that is neither responsible nor response-able. Among the multiple solutions that are offered in the case of moving out of vulnerabilities leading to straw burning, only few focus on building resilience and capacity for continuous engagement. The efforts by organic farmers in privileging human–ecological relations over anthropocentric, productionist paradigms is one notable example.

DECLARATION OF CONFLICTING INTERESTS

The author declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

FUNDING

This work was funded by Netherlands Organization for Scientific Research [Nederlandse Organisatie voor Wetenschappelijk Onderzoek], grant number 31399300, and DSM India.

NOTES

1. Agriculture science centres are block-level agriculture extension offices set up during the GR period to provide training to farmers on the scientific methods of doing GR agriculture. There are multiple factors that influence farmers' trust and relationship with KVKs. In our study in Punjab region, we found that majority of farmers we interviewed had trust in the knowledge and information provided by KVKs.
2. Others include social scientists, scientists, biogas entrepreneurs and civil society representatives.
3. This could still be due to the negative image associated to those who burn the straw and farmers were still hesitant during the introductions to openly confirm that they use burning as the method of straw management.
4. Studies have shown that there is a continuous rise in expenditure on crop production and continuous decline in the share of agriculture sector in gross domestic product. Most of the expenditure on crops is found to be on commercial inputs. Studies also found that a majority of the farmers from different regions of Punjab routinely borrowed money from local moneylenders as well as different credit agencies (Gill & Singh 2006; Gill, 2010)
5. Jhum cultivation or slash and burn agriculture or shifting cultivation where whole communities of farmers move to different locations after harvesting and burning the fields. The field is left uncultivated for more than ten years to allow it to naturally rejuvenate. In contemporary situations with rising population and environmental degradation, this practice has also garnered a lot of criticism.

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The Future of Farming: To What End and For What Purpose?

BHARAT BHUSHAN TYAGI and RICHA KUMAR

In this conversation, Bharat Bhushan Tyagiji, national award winning farmer from western Uttar Pradesh, and social anthropologist Richa Kumar, together attempt to analyse the alternative perspective of Tyagiji on the current crisis of farming in India, especially Punjab. Unlike typical alternative perspectives that uncritically glorify 'tradition', romanticise nature, and dismiss science and machines, Tyagiji's views are refreshingly different. His focus is on the present; he is not enamoured by tradition or by so-called traditional knowledge. At the same time, he seeks to put science back in its place—within a larger discourse and appreciation of the knowledge of living in this world with meaning and purpose. He argues for working with scientific knowledge rather than dismissing it entirely, and he wants to use technology as part of a system that also centrally values human labour. But before we can change agriculture, he argues, we have to first contend with questions of how we want to live, and what we want to value. This conversation is a small contribution towards helping us think through some of these vexing questions in the context of the future of farming.

Keywords: Green revolution, alternative agriculture, sah astitiva (symbiotic existence), agroecology, purpose of farming, maximising versus limits

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Acknowledgements: We are grateful to Professor Wiebe Bijker and the RRI group for giving us this opportunity to write something together and to two anonymous reviewers for their detailed comments. Richa Kumar would like to thank Harish Naraindas, Naveen Thayyil and Shambu Prasad for their helpful suggestions.

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Science, Technology & Society 25:2 (2020): 256–272
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820902966

In Conversation: Bharat Bhushan Tyagi and Richa Kumar

I (Richa Kumar) first met Bhaarat Bhushan Tyagiji (BBT) when he came to IIT Delhi to attend a conference on India's soils. Almost gaunt, with sunken cheeks, a white stubble and spectacles, he was in his trademark white kurta pajama. I tried to arrange for someone to translate the proceedings for him, little realising that this Delhi University science graduate from the 1970s, already knew more about soils than most people in the room. When he got up to speak, it was a surprise—here was someone not stuck in the thralls of tradition, nor swept away in the spectacle of modernity.

Subsequently, we were both invited to participate in the conference on 'Burning, Biofuels and Bettering Farm Life: Pursuing Responsible Research and Innovation Through Mutual Learning' organised by Maastricht University at IIT Delhi, and then asked to write about our joint perspective on the issue. Since then, we have had multiple conversations about farming, farmers and what do we see as possibilities for the future. We have chosen to present a summary of those ideas, not in the form of a traditional article with joint authorship but as an interview, with Tyagiji as the proponent of a particular world view about farming that he has been practising, and propagating, for the last twenty years, and I, as an interlocutor, based on my academic training and fieldwork as an anthropologist of agriculture.[1]

Tyagiji grew up in Beehta village in Bulandshahr district, which is in the heartland of the Green Revolution in India. His father insisted that he come back to the village after earning a BSc degree, and he began farming in 1975 using Green Revolution techniques learnt from scientists at the research centre nearby. Within a decade, he was disillusioned and started looking for alternatives. It took another decade for him to develop an alternative understanding of farming based on the ideas of the mystic-philosopher Shri Agrahar Nagraj.[2] These ideas have been implemented on his farm over the last two decades, which has also been formally associated with the National Centre for Organic Farming, Ghaziabad. He has shared his alternative world view with many other farmers over the years, and even been interviewed on national television. He received a Padma Shri (India's fourth highest civilian honour) for his work in 2019.

In the following interview, I critically engage with Tyagiji's ideas based on conventional critiques of the alternative agriculture movement in India—uncritical glorification of tradition, romanticisation of nature, dismissal of technology and machinery, dismissal of science and a focus on the responsibility of the farmer for his/her situation. It is interesting to note that his response is contrary to the typical alternative agrarian framing that has become popular in recent years in India.

His focus is on the present; he is not enamoured by tradition or by so-called traditional knowledge. At the same time, he seeks to put science back in its place—within a larger discourse and appreciation of the knowledge of living in this world with meaning and purpose. He argues for working with scientific knowledge rather than dismissing it entirely, and he wants to use technology as part of a system that also *centrally* values human labour.[3]

Our discussion begins with a diagnosis of the ills of farming today. Farmers have been incentivised to destroy the environment, to damage their own health and that of others, and to compromise on their ability to farm in the future. Many farmers have willingly taken the bait, seen short-term gains, but are now rueing their fate, whether in Punjab or in Vidarbha. In the process, they have also become disempowered—their understanding of farming and of how to work with nature has been reduced to nought—they are at the mercy of the agro-chemical intermediary and dependent on the scientist.

Tyagiji then presents his alternative world view which seeks to understand the working of the natural system and to do farming in collaboration with it. This requires farmers to throw away the yoke of the Green Revolution, which made them into mute implementers of technology from outside. There are no techniques, nor a package on offer, but a set of principles about how nature works, and a set of rules derived from those principles, all based upon the observation of the natural world. Farmers (and anyone else wanting to understand this) are invited to observe the natural world for themselves to grasp these principles and to figure out how to translate these principles into activities on their farm.

In the course of this discussion, we both agree that there needs to be a change in the broader socio-economic and cultural frame through which farming is understood and evaluated before farm practices can change meaningfully. But he believes farmers are responsible for their own situation (why have they taken the bait?), and they need to develop their own understanding about why they are farming, what is it that they want out of it. Once they gain an understanding, things will begin to change on the farm. Having successfully practiced what he preaches for the last two decades, and having talked to thousands of farmers during this time, Tyagiji believes farmers are not as disempowered as it may appear.

I, on the other hand, believe that farmers have been systematically pushed into a corner, and even if they, individually, want to change their farms, the odds are stacked against them—the monoculture model, the treadmill of agro-chemicals, the inevitability of debt, the caste, class and gender relationships framing their lives, and even the aspirations of urban life. Unless broader discursive frames are challenged in agrarian policymaking and research, most farmers will find it an uphill task. This piece, then, is meant as a contribution towards helping us figure out what are the questions to be asked, who should be doing the asking and what are the possibilities for the future of farming.

Richa Kumar: Tyagiji, we have been discussing about air pollution across northern India resulting from crop residue burning, especially in Punjab and Haryana. When rice farming began in the region in the 1980s, farmers did not burn the stubble after harvesting their crop manually. Today, the practice has become indispensable—it is no longer stubble but 1.5 to 2 feet of straw left behind by harvesters that is very hard to plough in; since farmers need to plant wheat quickly before the sowing window ends, there is not enough time or labour available to collect the straw and dispose it off. The harvest is a function of *when* farmers are able to sow the rice crop—the government has mandated that it cannot be sown

before 10 May or transplanted before 10 June, to conserve groundwater and utilise the monsoon rains. But that delays harvest and provides a very short window post-harvest. With all these constraints, what are farmers supposed to do?

BBT: There are many interconnected questions here—of productivity, of labour, of fertility, of time. Let's begin with the question of productivity. Through the Green Revolution model, we increased the productivity of one thing using water, machines and chemicals. Punjab is the heartland of this model. But why did we want more of one thing?

RK: Punjab's farmers were exhorted to increase productivity to feed India. They became our food bowl.

BBT: But how much more was enough? The language called for 'maximising productivity'. What did we mean by maximum? Farmers were incentivised to grow rice in a region where rice had never been grown. And growing rice monocultures could only happen at the cost of other things. We wanted most output at least investment. But how is that possible? Increasing one thing is bound to create imbalance. Through science we have speeded up the system, but done so without a goal.

RK: But the goal of the state was to increase wheat and rice production to feed a starving nation.

BBT: Did we ever ask what kind of output is to be increased? Why only wheat and rice? And how much of it is needed? Does maximum output have an upper limit? Did we ever ask this question?

RK: But we cannot blame farmers for going along with what the state incentivised them to do. The state provided free electricity, subsidised the growth of tube wells, and purchased rice at increasing MSP year after year. And then for years, the Punjab agricultural department recommended the burning of fields—until ten years ago. Farmers cannot be held liable for the health of the people of Delhi. With all that stubble burning, their own health is at stake too.

BBT: It is time that farmers realise this. That their own lives are at stake, too. Once farmers realise that the straw is not garbage (*kooda*) or residue, that it is the most important input to improve their soil's fertility, once they realise that they don't need inputs from outside, they will automatically not burn it.

RK: Even if they realise it, how do they implement it? Burning it is the price of a match stick compared to the costs involved in collecting it, even if farmers can sell it to someone who makes biofuel or some other product with it. Farmers need to make money to survive.

BBT: We need to go back to the fundamentals of farming. How do things grow in nature? Have you observed what happens in an empty patch of land? The minute there is enough moisture, weeds come up. The earth's process of growth (*dharti ka vikas kram*) is to maintain its fertility—wherever you see nature, it works that way. Whatever the earth produces, it does so for its own fertility—the grass, the insects. As the seed grows into a plant, its overall product or residue—the roots, leaves, stalks—goes to the soil and that increases soil fertility. Burning the residue deprives the soil of nutrients. All the carbon goes into the air. The microorganisms are destroyed. The moisture holding capacity of the soil is compromised.

You see, soil fertility is not a result of chemical elements alone. The physical and biological structure of the soil is critical. There is a set of activities that take place between the soil and the seed. The roots of the seed produce a sap in the soil, through which there are reactions in the soil. Microbes are attracted to this sap with its scent. They help solubilise materials that are available in a static form in the soil enabling the root to absorb it. The physical and chemical structure work in tandem with each other from the very beginning and create a balance.

Monocropping has created disorder in the chemical balance (*ras santulan*)[4] of the soil and external inputs have further aggravated this. The work of microbes is now relegated to companies. Only a single type of biomass is available to the soil. External chemicals create a chemical imbalance and stop the microbes from working.

RK: But we are able to use techniques like soil testing to tell us what is deficient in the soil, and by adding those specific nutrients, we can maintain the soil's fertility and ensure the nutrients are being directed to the desired monocrop.

BBT: Let us understand the soil test. It gives us twelve types of indicators, including information on specific elements. Regarding the pH, electrical conductivity and carbon level, the test can give a good approximation of their levels. But the information regarding chemical elements will not remain valid if it rains, or if you irrigate or grow something. Immediately, the chemical properties of the soil will change. Also, the recommendations are given based on the crop you will grow. But you can never accurately predict the levels that are needed for your specific variety. By the time the recommendations are given, the chemical levels in the soil may have already changed. We are stuck in the discussion of major elements or micro elements, but ultimately, soil fertility can be improved by fixing the method of cropping (*phasal pranali*) without worrying about the exact levels of elements. As you increase mixed cropping, weeds disappear.

RK: Does mixed cropping mean going back to the traditional way of farming? Doing things the way our parents or grandparents did?

BBT: No, my parents did multicropping for our family needs based on their personal circumstances and the environmental situation. They had no means of irrigation, no resources for ploughing. Land in the village had been divided according to the four types of soil, and people grew a different combination of crops on each.

But my parents did not know why they were doing these things. I asked my father, 'Why are we weeding again and again?' My father replied, 'My father also did it all his life; I, too, have been doing it all my life. But you are educated. There must be something in this grass. It is worth thinking why the soil even produces it. Why is there this battle, this antagonism, between grass and humans?'

Once you grasp the principle that all existence is mutually beneficial existence (*sah astitva*),[5] then it becomes easy to understand that there are no weeds. All that grass is simply an indication that the soil is trying to improve its fertility in that climatic zone. My parents did not know about the principle of mutually beneficial or symbiotic existence.

RK: Can you explain this principle?

BBT: There are four principles that I have observed from the working of the natural system: mutually beneficial or symbiotic existence (*sah astitva*), diversity

(*vividhataa*), space utilisation (*ghanaakaar*)[6] and agroecology (*naisargikta*). The first is about realising that nothing exists in and of itself. Everything exists in a mutually beneficial or symbiotic relation to other things and those relationships arise on the basis of a natural order.

The soil gives nutrients to the plant, the plant gives back to the soil. Both work in complementarity to each other and support each other's growth in a symbiotic way. This relationship is framed by the principles of complementarity (*poorakta*), usefulness (*upyogita*) and prosperity (*samriddhi*). There is no antagonism between soils, plants, animals, humans in the natural system—they are complementary and they support each other's growth. We have created conflict by growing monocrops.

For example, we have broken the mutually beneficial existence of maize with four other crops—that would have left no space for weeds and insects/diseases would become balanced (*keede aur bimariyon ka santulan ho jata*). The scent of various plants, the sap from their roots, the microclimate, this would ensure no insects came.

RK: Is this related to the principle of biodiversity?

BBT: Yes, diversity is the second principle of nature. Grains, pulses, oilseeds, fruits, timber, vegetables, spices, medicinal plants, fodder, roots and herbs, scented plants are all to be found in nature. When nature provides all of them, why should we grow only one monocrop? Why are our policies promoting only cereals or sugarcane? Or even a pigeon pea cluster?

The third principle of density or space utilisation (*ghanaakaar*) is important to understand how this diversity can be recreated on the farm. Between the height of the atmosphere and the depths of the earth, only some portion of it is habitable.[7] From just below the ground to almost 40 feet above the ground is the spectrum on which we see most of the flora. We have this entire three-dimensional space that we can utilise, but we are growing plants only in a single layer. We need a multilayer system—not vertical farming but multiple cropping with diversity. This is the secret behind the productivity of the system and this directly feeds into the economics.

Underground crops such as potato, radish, turnip, carrot and beetroot improve the physical and chemical properties of the soil. They take away chemicals from the soil and dilute it, in the process greatly improving soil fertility. Next come the pulses which grow up to 2–3 feet. Cereals grow from about 4 feet (rice) to 5–6 feet (maize) to 7–8 feet (bajra). Then you have sugarcane at 10–12 feet, horticulture crops such as banana, papaya, guava and then mango trees.

To implement this requires not only space management but also time management, to ensure that something is being harvested from the field at any given time in the year. Every plant has a given spatial spread horizontally and vertically (*phailav*, *vistaar*). The rule of spacing is such that no plant should be affected by another's spread (*vistaar*). This will help decide the spacing and seed rate and give an estimate of productivity.

The rule of time takes into account how much time is required for a plant to complete its activities related to its productivity and nutrition. Early varieties, which are popular because they allow you to produce more for the market (by enabling

the taking of a second or third crop in the same field) will have less nutrient value because they don't get enough time to complete the required activities for complete maturity. They are also unseasonal crops. Further, when you increase the quantity you end up decreasing the quality, in terms of its nutritive value.

RK: Don't you need adequate water to be able to grow many of these crops you have described?

BBT: That brings us to the last principle of agroecology or understanding what the natural endowment of a region (*naisargiktaa*). The choice of plants should be made according to the local climatic zone—the temperature, the rainfall patterns and the changing of the seasons.[8] The structure of the human body and the flora is shaped by the climatic zone. The fertility of a region is influenced by the seed characteristics (*beej sutra*) of that region and the properties of the soil. For mixed cropping to be successful, all four principles need to be understood for a given region and choice of crops made accordingly.

RK: Does this mean you propose taking up *desi* (indigenous) seeds, *desi* animal breeds, etc.? Like that proposed by Subhash Palekar's zero budget natural farming system (Münster, 2017)?

BBT: The principle of agroecology (*naisargitkaa*) insists on familiarity with the plants that are local varieties. The local is defined according to the temperature, rainfall pattern and season changes. And this changes every 500 km or so. It is not a question of *desi* or *videsi* (indigenous or foreign). The definition of *desi* or local is applicable only to a given agroecological region. The Gir cow is not native to all parts of India and there are hundreds of local breeds. It is humans who are making efforts to ensure higher milk yields through cross-breeding of cows. If you stop the process of artificial insemination, after three or four reproductive cycles, the native animal comes back into its original form as suited to the local agroecology. There could also be non-native plants or animals that have become a part of the local agroecology.

RK: Most people are surprised to know that tomato and potato are not native to India, but they form the basis of the North Indian diet. They were brought from Central and South America more than 400 years ago. But what about encroaching species such as gajar ghas and eucalyptus, which have become an inseparable part of the local landscape? It is claimed that these have had detrimental effects on the local agroecology.

BBT: Even in nature, there is constant transfer of seeds through birds, through animals and even cross-breeding (*sankarikaran*). When a non-native variety takes root and survives in a given agroecology, it becomes a part of the landscape. If it is unable to cope with the local environment, it gets diseased and loses its power of resistance, eventually dying out. There are now grasses that are competing with gajar ghas and insects eating it away. But eucalyptus is being promoted for timber. That is not the fault of the eucalyptus.

With the coming of the Green Revolution, for all the four types of land in our village it was said add water, chemicals and everyone can grow rice and wheat as monocrops. Ignoring the fact that different types of land had different types of

soil that was useful for growing a different, but complementary set of crops, we were told that through technology it can all become 'productive'. With machines, tractors, small farms increased in size, trees were cut down and people shifted wholesale to the new system. But in this, productivity was defined very narrowly as the grain output of the monocrop. Everything was put at stake for the grain. The grain's thirst for water was quenched through canals and then through tube wells. And in the process, we have created imbalance not only in the fields but also in the larger climatic system.

RK: You mean the carbon footprint of agriculture contributing to climate change?

BBT: Not just the increase in temperature. That, of course, is a problem with its destabilising impact on the wind patterns and on the ability of plants to survive in their current ecosystems. But what I want to emphasise is another kind of imbalance resulting from groundwater mining. With the heat of the summer on the subcontinent, the hot earth would send a signal of thirst for the monsoons to arrive and quench this thirst. But now, as we have drawn more water out from the ground, there is too much moisture/humidity in the air. That signal has become distorted; in some cases, it is no longer sent (*dharti ki pyaas ka sanket khatam ho gaya hai*).

Excess moisture has led to fungal diseases, bacterial diseases and insect pest attacks. These are all a result of unseasonal moisture (*bina mausam ke nami*). The mango belt of western Uttar Pradesh was unaffected by pests and diseases (*sabse nirogi paudha*) as long as the groundwater level was at 10–20 feet. As soon as we pulled out the water, the mango started getting diseased. Both *desi* and grafted (*kalmi*) mango trees were affected. The groundwater was essential for the orchard's health.

RK: This seems to take us back to mutually beneficial existence. We have failed to understand the logic of the water being underground or even the minerals and metals being underground. You may have heard of the water retention capacity of bauxite and all the devastation taking place because of bauxite mining in the forested hills in eastern India. Our model of development presumes that mining of water and other materials is inherently a good thing. Before the climate fiasco, the only critique was that they are non-renewable resources (much of the water mined in dryland areas can never ever be replenished), so they should be used judiciously. What you are suggesting is that water mining is also creating a different kind of climatic imbalance.

BBT: Yes. And the climate imbalance is mirroring the imbalance of our bodies. Mangoes are now part of long value chains, which is making things available even in off season, all for the sake of profit. There is extra expense on transportation—mangoes from Delhi go South and those from the South come to Delhi. They eat our stale mangoes and we eat their stale mangoes (*unka baasi humne khaya, apna baasi unko khilaya*). Constipation, cancer, blood pressure, these are all the diseases of eating stale food. Health is not on the horizon in agriculture at all, only profit is.

RK: Nowadays, no mango is consumed in urban India without it having gone through a carbide diet. It will not survive the journey to our plates without it! This is very similar to the notion of the 'metabolic rift' suggested by food regime theorists Harriet Friedmann (2005) and Phillip McMichael (2009). Drawing upon

Karl Marx, who coined the term, they argue that the commodification of agriculture through the process of conversion of organic resources to inorganic commodities has broken the cyclical nature of the relationship between nature and human beings.

BBT: Farmers have forgotten their own available inputs because all inputs are supposed to come from the market. Because of standardised inputs, not only are you dependent on the market but your skill, your craft, your expertise in converting variability into standardised output is also lost. This is the story of Punjab, why farmers are burning their fields. Agricultural sciences are conducting research only through the lens of business. Regardless of consequences, nature is being shaped into arbitrary designs (*manmani karke design mein dhal dein*). The only metric is money, in the process ignoring the larger principles of the natural system, health and the environment.

RK: But isn't there some form of a romanticising of nature in your framing?[9] What about the wild animals, the jungle, the hardships, the pestilences, the back-breaking labour that our ancestors dealt with—not to mention many communities having to deal with it today. All those elephant raids on the crops? Hasn't mechanisation and chemicals like DDT tamed this wild nature, helped firmly establish the benign agricultural landscape, which is now being taken for granted by natural farmers, when they make a call to mimic nature?

BBT: The call is not to mimic nature. It is to understand the working of the natural system and to work with it. We need to distinguish between the natural system (*vyavastha*), which is a set of principles that regulates events in nature, and the events (*ghatnakram*) themselves. The jungle is also part of nature, humans are also part of nature. That part of nature where humans have made efforts along with the natural system is known as agriculture. The events that we see in the jungle and in that part of nature which has been changed by human effort are all shaped by the same set of principles.

Humans have not made the natural system. The relationships between microbes, plants, the elements, the wind, water, oceans, mountains—it exists regardless of whether we humans exist or not. Whether it will exist in the future one cannot say and in what form it existed in the past is also based on conjecture or theory (*anumaan*). But for the present, we can say that the natural system works to support life on the earth. It functions based on a set of principles which regulate the various parts of the system and create a balance that supports life.

RK: The theory of homeostasis similarly talks about the maintaining of life through dynamic interacting processes on earth.

BBT: The lion is not the enemy of the deer. It will kill for satisfying its hunger. It won't kill all the deer. Every element or living thing stays within its own boundaries. It doesn't interfere in the existence of another element or living thing. But humans are the only species that can, and have, wilfully interfered with the workings of the natural system. We have made our own principles, we are attempting to regulate the system and we are trying to create our own balance. But, instead, we are creating imbalance.

The natural system strives to maintain itself to support life. Plants continue to produce seeds that turn into plants. Animals continue to reproduce themselves.

Humans are also a part of this natural system, but through their knowledge, they are also able to interfere in its working. Through the process of development, medicines and hospitals, we have kept more sick people alive for longer. We have reduced the mortality rate. But through the same process, we have created more sickness—cancer, heart disease, etc. We may have saved ourselves from smaller problems, but are now staring at much bigger problems—we may have brought irrigation, but climate change can be devastating in its impact. Imagine what diseases might be awaiting us with the imbalance in the earth's temperature, changes in wind patterns and the impact on plant life.

RK: Are you against all development?

BBT: When humans began saving seeds, levelling land and practising settled agriculture, they began to significantly transform the natural world. Humans have used their knowledge and skill to create a world different from the jungle. Human innovation is worthy of respect. There is nothing wrong with innovation per se. The problem arises when we innovate in opposition to the principles of the natural system. These principles are applicable in the jungle and in that part of the world which is inhabited by humans (both of which have been transformed by human action). But today's farming practices and style of living means going against nature. Whether intentionally or unintentionally, we have failed to understand its functioning.

If we want to get out of the mess we have created, we have to understand the principles of the natural system and live along with it. We cannot go back to living in nature—that is an extreme position. But we cannot create our own system in opposition to it. If we are hot, then we should search for a way to cool ourselves, but through some natural means.

RK: So you are not against technology or machines?

BBT: I am not against machines per se. But when we gave importance to machines, we devalued human labour in the process. The use of machines ended up in the exploitation of people, by taking away employment.

RK: Wendell Berry (2009), a farmer and activist in the USA, has written about the simultaneous production of unemployment and belly fat through the coming of machines. In India, caste has played an important role in shaping attitudes towards physical labour. Youth from historically farming castes (typically other backward classes) consider physical labour as beneath their social status. Their aspirations are for white-collar jobs (mental labour) in an urbanising India. Many of the caste-based agitations of the Patels, Marathas and Rajputs are linked to this question of labour and employment.

BBT: The only thing that is produced without much expense every day is the possibility of labour through the body. Unless we pay respect to labour, unless we establish the systems to promote labour, we will continue to promote unemployment and poor health. Labour and intelligence are our assets. We cannot allow machines to entirely replace them.

RK: You are reminding me of the example of the tomato that was bred by agricultural university scientists in the USA so that it was hard enough to be harvested

by mechanical arms and would ripen all at the same time using ethylene gas so that it could be grown on a larger scale. The problem they were trying to solve was the perpetual shortage of agricultural labour in the USA (Hightower, 1972). We've adopted that same model in a country which is labour surplus. But even then, there is something to be said for efficiency that comes from using machines.

BBT: Why is labour evaluated only in relation to time or profit? Can it be linked with usefulness also? Do we need it for profit or do we need it to live? Who gets to decide? Human beings need relationships to live and to fill those relationships, machines are no substitute. Can machines be a source of trust, relations, love and justice between people?

Like the rules of distance and time, the rule of organising labour in agriculture requires establishing a balance between the use of machines and the use of human labour—maintaining the appropriate distance between the labour of machines and the labour of humans.

RK: Are you suggesting that efficiency in and of itself is of no use?

BBT: To what end are we speeding up things? With machines more land can be farmed by fewer people. Why is that better in and of itself? We gave importance to machines and created unemployment. To get rid of unemployment, we cannot get rid of machines. I don't contend that machines are bad in and of themselves. But what should be the size of machines, how much should they be used? These are the questions that need to be asked and decided upon.

RK: You are emphasising that agency lies with the self. Your approach is that farmers can become responsible for themselves; they don't need to rely on anyone else from outside. Once they change their mindset, they will value things differently and then act according to the new set of values. They will innovate while working in tandem with natural system and within the four principles. That is the pathway to productivity, good health and a workable livelihood. While all this seems logical, what about the larger structural constraints that farmers find themselves in? You may recall at the soils conference we discussed how an individual farmer will find it impossible to change his/her farm unless region-level changes take place. One mixed farm in a sea of monoculture will not be able to last very long.

BBT: The system created by human beings has not been made by a single person alone. Everyone has contributed to it. Even if the research may have been done by one, or the technology made by a few, everyone else has accepted it, or not gone against it. That is why it is working.

But that one person is never an 'individual'. He or she is always embedded in family, in relationships, in society. The day that one person makes an effort to understand the world around us, the day they start thinking about the natural system and talking about it, then conversations can begin. That person can begin to live based on understanding, and not just circumstances. We can continue to live in the same society in the same way. But our views will have changed and we will accept what is correct, we will talk about what is correct.

RK: But how can one farmer in Punjab stop the burning and survive economically when there is little support to him/her in mulching the straw into the ground

or even taking it away in the time frame required? Even if she thinks differently, where would she even begin? If she wants to grow something other than paddy and wheat, where is the market for it?

BBT: Let me tell you my own story. For ten years, from 1987 to 1997, I remained very disturbed with the state of my farm. I had adopted the ways of the Green Revolution under guidance from the Agriculture Research Centre starting in 1975, and within a decade I could see that everything had gone out from my hands into the hands of the market—inputs and output. My land was suffering. Soil fertility was going down. There was misuse of groundwater, the quality of food was not good. I tried to look for alternatives in India and elsewhere. I spoke to many scientists, many farmers around the country. Everybody had techniques, but no one explained the fundamental principles. I wanted to set up an orchard and people told me different measurements in feet, in meters. But no one explained to me the rule of spacing or distance—ensure that no plant is overshadowed or comes in the way of any other plant.

Should I listen to scientists? Or should I listen to farmers who were using new techniques? NODAP farming, zero budget farming, saindhriya farming, sajeev farming? Which made sense? Some places emphasised the cow, some highlighted the stars (*nakshatra*), some focused on seed rates. Each of them had some aspect that was useful, but they were not complete in and of themselves. And the techniques also changed with location. What worked in Maharashtra didn't work in Uttar Pradesh. Techniques of the hills didn't work in the plains.

All these new techniques, while they may have reduced the input cost of farmers, did not improve the economics or the income prospects. There was only marginal improvement, and initially, there was greater risk as the output might fall. I tried bee keeping, animal rearing, processing. But all this was done piecemeal. There was no integrated model.

In 1997, I met Shri Agrahar Nagraj, who had spent many years in contemplation in Amarkantak, Chattisgarh. He explained to me the principle of mutually beneficial or symbiotic existence as the basis of the working of the natural system (*vyavastha*). He said, you go out and see it for yourself. When I started observing nature, I understood that the basis of life is symbiotic existence (*sah astitva*). I realised by listening to nature, I could get out of my problems.

This was not only about understanding relationships within nature but also my own place in this natural world—my own relationship with nature and with others in society. I had to first answer the question why I was farming. What did I want to get out of it? The answer was not about fulfilling my physical needs alone. The processes of life (*jeevan*) were not only about sustaining the body but more importantly about fulfilling our innate needs for respect, justice and trust. I was part of a family, part of a society and my actions were always embedded in this realisation. I had to learn to take responsibility for myself—and the web of social and natural relationships I was a part of (*sah astitva*)—and work with this understanding to determine and fulfil 'my' needs.

Through an understanding of the four principles based on observing the working of the natural system, I began to remake my farm. My production increased

in quantity, improved in quality and grew in diversity. Today I grow 9–10 crops in my farm at any point of time. But I soon realised that it was not enough to see production alone. I had to understand and remake the entire system from production (*utpadan*) to use (*upyog*) (not consumption [*upbhog*])—and I had to take it up with responsibility and integrity. To improve the economics I needed to reach the consumer directly, making it necessary to move into processing. I needed to get a grasp on what kind of processing is possible, what market linkages may need to be built. I began to see the relationship between production, processing and marketing, and have undertaken a certification process (Participatory Guarantee Scheme of India, organic certification programme by the government) to ensure trust in these relationships.

RK: Reducing it to the level of each individual's own responsibility is similar to the neoliberal perspective that has become prevalent over the last 30–40 years. With the decline of the welfare state, people are now supposed to be responsible for their own development.

BBT: This is not about an individual. We are not individuals—we have to begin by understanding this—by recognising our relationship with others in society and with nature. By viewing those relationships through the lenses of respect, of justice, of trust. Our actions are always embedded in society, in nature. Once we develop this understanding and talk about it with others around us, we begin to realise the possibilities of what can be done.

RK: What you are describing might work for large, capital-rich, upper-caste farmers who can afford to handle the transition period. What about the ordinary one acre farmer with poor quality land? Is there a pathway for such a farmer?

BBT: The ability to labour (*shram*) and the ability to understand (*samajh*) is in everyone's hands. These are our assets. Instead, we are assuming assets to be land, machinery, money. These are all conveniences or facilities (*suvidhayein*). If there is understanding, the big farmer will on his own join together with the small one. The big one has land, the small one has labour. There is no labour problem—rather, the farmer has no money to pay for labour. Instead of labour, he has got machines. He is in debt due to the tractor loan. The labour was used when it was needed, now the tractor is sitting there all the time. How to make it useful all the time? You have to pay for it even if you don't use it.

By giving big machines to the big farmers, we have destroyed the big farmers and the small ones. If all farm work will be done by drones, what will people do?

RK: But historically, it is the big who have exploited the labour of the small. Labour has never been valued properly.

Lack of understanding of our place in this world, of the relationships we are embedded in—lack of appreciation of the process of life, that the need for respect, trust and justice is the same for all—is at the root of exploitation. A farmer with half acre land, a farmer with no resources, a farmer without any means of irrigation, they can all begin to understand these relationships entwining their lives. With this understanding emerges a whole series of options. Ultimately, it is a matter of understanding, not just seeing a working model somewhere else but grasping the

principles of nature and of our own place within it—and of figuring out what are the possibilities based on one's own circumstances. The farmer does not need the agricultural research system or even a tractor. There is no need of scientists. Farmers can become empowered to do this on their own with the support of other farmers.

RK: Farmers may not need scientists. In any case, over the last several decades there has been a call to destabilise the certainty of scientific knowledge. Scientific knowledge produces a set of claims about the natural world that are broadly accepted. Scientists do research, they make propositions, others evaluate it and once there is agreement, those ideas are published, and perhaps gain general acceptance. But that is true of all knowledge—even the four principles that you are suggesting are one set of claims about nature. Farmers may choose to accept the claims of scientists or they may choose to accept your claims—you are the expert here in place of the scientist.

BBT: The agricultural sciences, unfortunately, have looked at the world through partial eyes—the botanist doesn't know about microbes, the entomologist doesn't know about soils or minerals—our entire education system, agricultural sciences, medical sciences suffers from this specialisation. No one is looking at the whole farm. The day scientists start understanding the natural system in its entirety and begin working with it, not against it, then they become important allies.

At the same time, science (*vigyan*) is not enough. Science can only tell us about the natural system and what can be done to work with it. But it cannot tell us why we are farming? What is the purpose of living, of farming? That is in the realm of a different kind of knowledge (*gyan*), but it is essential to begin there. I farm because my body remains healthy and my bodily needs are fulfilled. But I still need to ask the question: What are my needs? It is only through a process of discernment (*vivek*) that I can answer this question.

The approach of least input and maximum output is bound to be exploitative of something or someone—the earth, humans, the environment. This is a result of not discerning our needs. If we understand the purpose of our actions and discern our needs, then it is possible to make money and save the environment.

RK: Those are fundamental questions you are asking about the purpose of human life itself. How do we begin to have conversations about our limits? But at the same time, there are systemic processes that generate inequality and lead to exploitation.

BBT: Once there is understanding, these systemic processes can begin to be challenged. Where there is lack of understanding of the natural system and how to live in it and with it, there is bound to be exploitation. Farmers in the past grew many crops, worked with the seasons, they didn't have many resources. But that doesn't mean they understood the working of the natural system. Earlier there were fewer opportunities to make mistakes. But when the opportunity arose to make mistakes, the farmers of the past made them. Why did the astrological sciences, the mixed cropping all disappear? Was any of it not correct? If it was correct, it would have stayed, it would not have been nullified so easily. Agnihotra farming, biodynamic farming, goat farming—they are all saying that earlier knowledge was correct. But if it was correct, how have we reached where we have today? No farmer is willing to go back to the past. No farmer wants to use the plough.

RK: I understand that no farmer wants to use the plough. But we cannot wish away the colonial past and simply put the blame on farmers and say their knowledge was incomplete, hence it got replaced by something else. It was not a question of knowledge alone. The institution of the zamindari system; the exploitation of the majority by the local elite in collaboration with the British; the forced cultivation of cash crops such as jute, indigo and opium, even wheat; the systematic destruction of the agrarian environment including water harvesting systems; privatisation and over-exploitation of the commons, not to mention the horrific man-made famines that killed between 13 and 30 million people between 1870 and 1910. We cannot forget that. There is a crucial link between knowledge and power. Certain forms of knowledge related to farming were systematically devalued in the face of science.

BBT: But what happened after Independence? No one stopped us then. And for the last twenty years at least, people have been talking about organic. Still why is agriculture in such a deep crisis?

Our privileging of science as the ultimate form of knowledge has been deeply problematic. Science can only tell us how things work. It cannot answer the question why things are the way they are. Why do I live? Why do I farm? It also cannot tell us how much we need to fulfil our needs. Unless we understand our place in the natural world and then figure out what do we need to live in this world, we are aimless. We are maximising everything, speeding up everything without any end. If I haven't decided my needs, and my limits, I have become the all-destroying demon (*Bhasmasur*), so I end up destroying everything. Everyone can't become Ambani (the business tycoon).

Before we can fix agriculture, our own 'culture' has to be fixed. We have to understand the workings of the natural system and our place in it. That is all the knowledge that we need.

Postscript

My conversations with Tyagiji over several months in 2018–2019 on this topic have been critical in reshaping my own thinking about the 'problem' of agriculture. When we began discussions, I was focused on interrogating his claims about the natural world and its working—especially his claims about their self-evident nature—given my training in science and technology studies. I argued that all knowledge is claim-making, some more successful than others. We can never ever really 'know' anything.

Yet, as we debated, I realised that when he was talking about the natural world, he was also talking about human beings and their behaviour as an integral part of that world. As he was challenging the divide between nature and humans and between nature and society, he was also putting humans in their place—challenging our hubris. We can never hope to replace the natural world, we can only attempt to understand it. And to change our farms we have to first take on the responsibility to change ourselves—the way we think.

For some time, I misunderstood his emphasis on taking responsibility as individuals. I was interpreting this to be the rational, utility maximising individual of

economics and thinking of the neoliberal framing of pulling oneself up by the bootstraps. For him, such a being did not exist. Human beings could only be understood relationally—they were embedded in nature and in society. He drew attention to the universal human need for respect, trust and justice—all relational—and which does not change with time, place, gender, age, caste or religion. He argued that we had to first learn to live—with ourselves and others and with nature. Only then could we learn to farm.

For a researcher who has been struggling with transforming my own 'consumption' patterns towards more environmentally benign (if not, friendly) choices, his call to change our *vichaar* (ideas), before we change our *vyavahaar* (behaviour), made eminent sense. As long as I valued convenience and comfort, my companion would be ill health and the consequences would not be good for the environment! More importantly, he underlined the fundamental divide between what we call knowledge about *the world*—from science—and knowledge about *how to live* in this world, which may fall in the realm of philosophy. Yet, if we want to change anything in this world, we have to contend with questions of how we want to live, what we want to value—we need to have those conversations, first.

This initiative on responsible research and innovation has provided the space to begin having such conversations—at least between Tyagiji and myself. I hope that more such spaces can be created by researchers and practitioners where we do not shy away from asking these difficult questions.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

FUNDING

The authors received no financial support for the research, authorship and/or publication of this article.

NOTES

1. Our conversations took place in Hindi and I have translated them into English. Many words have not found an acceptable English translation, and this is noted in the footnotes wherever the word appears first.
2. Based in Amarkantak, Chattisgarh, Shri Agrahar Nagraj (1920–2016) was a mystic and philosopher who came up with an alternative philosophy about living in this world, known as Madhyasth Darshan, distinct from both materialism and spiritualism (see http://madhyasth-darshan.info/).
3. *Shram*, used by Tyagiji, is usually translated as labour, but this strips the word of its association with physical effort, hard work and a sense of righteousness towards the act of work.
4. *Ras santulan* is the availability of chemicals or materials in the soil that are needed for all the plants that are naturally growing in a given region in a balanced form.
5. *Sah astitva* is usually translated as co-existence, but it goes much beyond that and expresses something more about the nature of the relationship between two entities; I have used symbiotic existence, but that errs on the other side.

6. *Ghanaakar* is usually translated as density or cubic space, but it is better reflected as a three-dimensional spatial mapping of the hugely productive natural world.
7. Refer to Latour's 'critical zone' (Latour, 2014).
8. Temperature includes sunlight, and rainfall pattern includes air pressure (moisture, wind speed, wind direction), density and scent.
9. See Fukuoka (1978) for a similar approach.

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RRI Beyond Its Comfort Zone: Initiating a Dialogue with Frugal Innovation by 'the Vulnerable'

SARADINDU BHADURI and NAZIA TALAT

Responsible research and innovation (RRI) aims at mitigating the negative unintended consequences of technologies, developed by large business organisations, on society and environment. Scholars point out that the broader ethical underpinnings of RRI in terms of 'transparency, interaction and mutual responsiveness' are difficult to achieve in a typical business environment as conforming to these principles may erode the very competitive advantages the corporations seek to achieve through innovations. At the same time, the scholarship on frugal innovations by 'the vulnerable' puts forward an alternative narrative of innovations. Seeking to respond to the gap created by the apparatus of the mainstream market, and the State, these innovations reflect many pro-social motivations, and desire for inclusive development. The two discourses, however, remain isolated from each other. Our article is an attempt to initiate a dialogue between them. We intend to widen the scope and ambit of both RRI and the frugal innovation scholarships, which might help garner more policy and social support in favour of developing socially relevant, inclusive and context-specific innovations.

Keywords: Responsible research, frugal, grassroots, innovations, vulnerable, sustainable development

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Acknowledgements: We gratefully acknowledge the constructive critical comments from the special issue editors Wiebe Bijker, Poonam Pandey and the three anonymous reviewers of the journal. Participants of the conference at Indian Institute of Delhi made important observations. A study leave obtained from Jawaharlal Nehru University in 2016 helped the first author to interact with several frugal innovators in different parts of India.

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Science, Technology & Society 25:2 (2020): 273–290
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820902967

Introduction

The discourse on responsible research and innovation (RRI) has mostly focused on innovations in large business organisations. Scholten and Blok (2015) and Blok and Lemmens (2015) point out that 'transparency, interaction and mutual responsiveness' (Von Schomberg, 2011, 2013) towards stakeholders, the three cornerstones of RRI, may become difficult to achieve in such settings. Innovation is the primary source of competitive advantage in private firms, and *asymmetries* in information are seen as a means to survive and flourish in the market. This often limits the scope of responsibility and accountability of actors hoping to innovate responsibly, and, in turn, may dilute the mandate of RRI to help achieve the grand targets of sustainability, addressing climate change and poverty alleviation. Frugal innovation, largely, remained separate from the domain of RRI scholarship. These innovations, however, have significant overlap with the developmental goals of RRI.

In the present research, the top-down frugal innovations conducted by large firms are differentiated from the bottom-up frugal innovations done by the vulnerable groups of populations (Leliveld & Knorringa, 2018). Bottom-up frugal innovators are direct users of their innovations. Existing research points out the relevance of various social, non-market forms of motivation in pursuit of these innovations. We are interested to explore the way the three pillars of RRI, namely the transparency, interaction and mutual responsiveness, get unfolded in the bottom-up frugal innovation settings. These insights from bottom-up frugal innovations may help the discourse on RRI to transcend its own 'comfort zone', where its approaches and concerns largely remained Euro-centric.[1] Re-contextualised, and reframed, the discourse on RRI, however, holds potential to contribute immensely to the making of an alternative narrative on innovation and development, targeted to achieve the goals of sustainability and inclusive development better. A fruitful dialogue would also help such frugal innovations attract better policy support, at a time, when its usefulness and worth remain below the radar of policymakers and social elites.

The next section introduces and explores the concepts of RRI. The third section deals with the discourse on frugal innovations by the vulnerable, and the fourth section analyses how some of the elements of RRI are inherent in the frugal innovations by the vulnerable. Subsequently, we make a few concluding remarks.

Responsible Research and Innovation: The Contours of the Framework

RRI seeks to include the notion of responsibility, along with those of integrity, impartiality, honesty, lucidity and openness, in all scientific endeavours. It proposes to avoid, through precaution, actions that might lead to unwanted consequences and wants us to be better prepared to deal with such implications in case they could not be averted (Grinbaum & Groves, 2013). Governance of socio-ethical

aspects (Scholten & Blok, 2015) of research and innovation in new and emerging technologies is seen as a challenge in the current democracies (Stilgoe, Owen, & Macnaghten, 2013). This challenge calls for a new approach towards innovation, which would balance the economic with the sociocultural and environmental aspects (Blok & Lemmens, 2015). Invoking 'responsibility' in the innovation processes is seen as a prerequisite to achieve that balance.

The accountability of scientists in cases of uncertain and potentially harmful innovations remains contested. While certain risks of unwarranted consequences are unavoidable, the purpose and motivations of research may require clearer social assessment (Blok & Lemmens, 2015; Stilgoe et al., 2013). Emerging technologies typically operate in a regulatory vacuum. Such technologies often raise questions about their desirability, possible consequences as well as the nature of anticipatory measures (Guston et al., 2014). Therefore, *anticipatory* assessment of technology is important (Kuzma, 2007; Van den Hoven, Lokhorst, & Van de Poel, 2012). Perhaps for these reasons, scholars (Von Schomberg, 2011; Stilgoe et al., 2013) call for a shift in the focus of RRI, away from, merely, the 'governance of risk' to the 'governance of innovation'.

Von Schomberg (2011) argues that societal interventions in the research and innovation process at an earlier stage helps dealing with the uncertainties related to acceptance of technologies, as well as governance of their unintended impacts. He defines RRI as 'a *transparent*, interactive process by which societal actors and innovators become mutually *responsive* to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products …' (Von Schomberg, 2011, p. 9; 2013, p. 19).[2] Stilgoe et al. (2013) propose four dimensions of responsible innovation, namely anticipation, reflexivity, inclusion and responsiveness, as a framework for RRI. We consider these dimensions as the basic tenets of the RRI, around which we frame the contours of the intended dialogue between RRI and frugal innovations. An elaboration of these dimensions, as mentioned in Stilgoe et al. (2013), is, therefore, in order.

Anticipation includes systematic thinking with an aim to increase resilience and reveal opportunities for innovation, and shape the agenda for socially robust risk research through foresight, technology assessment, horizon scanning, scenarios, vision assessment and socio-literary technique to engage with existing imaginaries, in a participatory manner. At the same time, actors and institutions need to be reflexive regarding the norms in place.

Reflexivity is not only warranted at an individual level but also at the level of their social identities.[3] In the framework of RRI, reflexivity could be implemented through a rethinking of moral division of labour and enlarging or redefining the role responsibilities. The processes of reflexive capacity development among scientists and within institutions, and creation of connections between research practice and governance too enhance reflexivity.

Inclusion of internal and external stakeholders in the decision-making is another central feature of RRI. Inclusion of new voices in the science and innovation studies brings legitimacy to these studies. The scholarship has identified several ways to achieve this, ranging from consensus conferences, citizens' juries and

panels, focus groups, to science shops, deliberative mapping, and deliberative polling. Lay membership of expert bodies, user-centred design and open innovation could also, arguably, help achieve this objective.

The most important aspect of RRI, however, is to be able to be *responsive* to the challenges received from the society. In the literature, this has been sought to be achieved through numerous means, such as constitution of grand challenges and thematic research programmes, regulation, standards, open access, value-sensitive design and alternative intellectual property regimes[4] (Macnaghten & Owen, 2011; Stilgoe et al., 2013). Regulation is understood to alleviate the negative unintended consequences of innovative activity, especially on health, environment and social integrity. Regulation, however, appears with a lag, after an innovation has occurred, because of the requirement of evidence to support the harmful effects of the innovation.[5] The fact that regulation-making is slow, and, often, follows an innovation, path dependencies and locking-ins of (undesirable) technologies might occur before regulations intervene, making it difficult for the regulation to alleviate their harmful influences completely.[6] This is why the RRI framework proposes better foresight ('horizon scanning'[7]) and complementary risk governance mechanisms (Owen et al., 2009), in order to complement regulation-making from the very initial stage of the innovation process. Since RRI aims at grand problems of climate change, sustainable development, resource depletion and poverty alleviation, its framework and problematisation need to internalise the issues of power and the diverse interests of parties involved, Blok and Lemmens (2015) argue. The aims of 'transparency, interaction and mutual responsiveness' towards stakeholders remain difficult to achieve too, especially within a business environment, where innovation is the main source of competitive advantage and withholding information is seen as an essential means to survive and flourish in the market. Weeding out the so-called 'irresponsible' innovation governance structure is, therefore, fraught with serious challenges in such settings.

In addition, following the 'Collingridge's dilemma', it is difficult to predict social consequences of a technology in the very early stages of an innovation, making it difficult to turn back or make changes in a problematic technology at a later stage, when the technology is already well entrenched in the socio-technical system (Ribeiro et al., 2018). Some scholars argue that responsible innovation discourse has put more emphasis on the process part of it, without giving much thought on how making the process more responsible will shape the final outcome (Blok & Lemmens, 2015; Oudheusden, 2014). This may lead to ineffective policy formulation and implementation.

Frugal Innovations by 'the Vulnerable'

Frugality and Frugal Innovations: A Conceptual Overview

The term frugal or frugality is used to refer to the activities involving judicious use of resources and avoidance of waste (De Young, 1986). It reflects a wide range of

behavioural characteristics and search (or decision-making) processes in the various branches of social sciences (Bhaduri, Sinha, & Knorringa, 2018). In popular parlance, frugal innovation refers to doing more with less (Radjou & Prabhu, 2015). From a behavioural science perspective, Lastovicka, Bettencourt, Hughner, and Kuntze (1999) define frugality as the 'degree to which consumers are both restrained in acquiring, and, in resourcefully using, economic goods and services to achieve longer-term goals'. Adam Smith (1776, pp. 92–93, 124) referred to the idea of frugality in emphasising the role of experience in coming up with innovative solutions. These solutions are developed in the actual environment, and not in confounded set-ups (e.g., laboratory). Often the practitioners of knowledge are better equipped to offer such solutions. In addition, for Smith, 'being industrious' (Smith, 1776, p. 247) or 'judicious' (Smith, 1776, p. 249) too embody frugality. Gigerenzer (2008) and Gigerenzer, Todd, and ABC Research Group (1999) suggest that frugality in decision-making needs to be understood both from the perspective of the decision-maker as well as the environment in which the decision is made. Frugality, to them, refers to the satisfaction of needs using simple search criteria, rather than profit maximisation and constraint optimisation.[8]

The emerging discourse on frugal innovations can broadly be categorised into two groups. The, so-called, 'top-down' frugal innovation discourse analyses the changing nature of organising innovations, post-financial crises, to reach out to the bottom of the pyramid, by making products which are cheaper, simpler, yet functional (Radjou & Prabhu, 2015). This construct has attracted criticisms for not adequately taking up the normative and social challenges to resource scarcity and poverty in the Global South. Pansera (2018), for instance, appeals to reframe the frugal innovation discourse by making technology '… value-based, normatively framed, socially controlled, and democratically debated'.

This is what indeed the 'bottom-up' frugal innovation discourse intends to construct. This branch of frugal innovation discourse does not confine the people on the margin to be mere recipients of technologies developed *elsewhere*, but considers such groups as active contributors of knowledge in innovation processes. These innovations are based on the perceived needs of communities they live in, their local contexts and shaped by social relations (Bhaduri, 2016). Commonly, these innovations are alternatively called 'grassroots innovations'[9] or informal sector innovations.[10] For Bhaduri and Kumar (2011), these innovations respond to the gaps left unfulfilled by the State and the market. The innovators, in most cases, draw upon multiple forms (and the combinations) of knowledge base, ranging from locally available traditional knowledge to the individual experiential knowledge, to (less frequently) codified forms of knowledge available in technical manuals and books. Much of these activities are undertaken without any clearly defined timeline, planning or predetermined source of funding. These innovations remain socially controlled in so far as their designs and usefulness are an outcome of social networks (Kumar, 2016 (2014)) and local feedback processes (Manyati, 2014). The sources of finance for these innovative activities too largely remain local and

informal. Unlike their 'top-down' counterparts, or RRI, these innovations take place in the actual environments of their use.[11]

Table 1 summarises various aspects of innovation processes for the 'bottom-up' and 'top-down' frugal innovations.

It is evident from Table 1 that the 'bottom-up' frugal innovations do not stop merely by ensuring the access of the vulnerable groups to new technologies. They, instead, envision these groups as an active participant in the making of an innovation.

In this article, such a frugal innovator is considered 'vulnerable' for multiple reasons. To Mechanic and Tanner (2007), vulnerability is shaped by a multitude of factors and their interactions, including personal incapacities, developmental problems, disadvantaged social status and inadequacy of interpersonal networks. Brockhaus, Djoudi, and Kambire (2012) propose that methods for assessing vulnerability should be based on specific research questions rather than definitions. In the present case, the lack of formal education, access to financial and material resources necessary for a decent living contributes to their vulnerability in general. As an innovator, however, they are specifically more vulnerable because of their unconventional approach to innovations, which do not find support/appreciation among the mainstream scientists, innovators and social opinion-makers. The lack of social acceptability to their research methods (and knowledge base) makes it almost impossible for them to access credit for their innovative efforts even from public sector financial institutions.[14]

We now discuss the key characteristics of these innovation processes in order to return to our moot question; that is, how these innovations, and the narrative surrounding them, can widen the ambit of RRI, by highlighting the possible ways to better conceptualise some of the core underpinnings of RRI. The data sources are multiple, and this article is not based on any dedicated sample. Instead, it reflects on various surveys, interactions with innovators, and case studies the lead author and his team has conducted since 2007. In addition, we draw upon studies done by others in this field, and the various publicly available data sources and newspaper reports.

A caveat is perhaps in order. These innovations are mostly incremental in nature, reflecting adaptation to resource crunch situations. It is worth recalling that innovations in its pre-Schumpeterian avatar included even activities such as repairing of existing products (Godin, 2008). We must also note that the sites of these innovations are diverse, ranging from the clusters of informal sector enterprises to social collectives, to independent individuals of the countries in the Global South.[15]

Frugal Innovations by 'the Vulnerable': Motivation, Appropriation and Regulation

The innovators in our sample gave diverse responses with regard to the importance of appropriating their innovations.[16] Many innovators seem to be indifferent to formal ways of appropriation. This behaviour is commonly attributed to ignorance

Table 1

Models of Frugal Innovation

	Top-down Frugal Innovation	*Bottom-up Frugal Innovation (by the Vulnerable)*
Key actors	Large firms, often located in Global North	Individuals and communities located in Global South.
Role of external stakeholders	Comparable to RRI in business enterprises.	External stakeholders are welcome, but they themselves remain apathetic (or even antipathetic) to the worth of these innovations. In few cases, external stakeholders have assumed the role of sympathetic outsiders[12] to contribute to these innovation processes by bringing new knowledge, arranging finances and developing networks.
Main drivers/motivations	Market expansion, with the secondary objective to promote development.	Range from intrinsic, pro-social motivations of varying degree, to respond to local needs, to individual business interest.
Nature of knowledge and innovation network	Network is predominantly formal, involving mainstream actors of knowledge and innovation. The outcomes are in harmony with formal regulatory mandates of safety and quality.	Network is predominantly informal. Experiential context-specific knowledge remains important. The outcomes are often not in conformity with the formal regulatory mandates of safety and quality.
Scale and type of operation[13]	Predominantly large scale, global and through market mechanisms.	Predominantly local, small scale and through non-market mechanism.

Source: The authors.

about, and, non-availability of resources needed to adhere to, IPR. Though relevant, such an explanation is not sufficient. To us, their diverse response to knowledge appropriation means and mechanisms provides useful insights into the complex process of knowledge generation, motivation and social control of these activities.

We mentioned that such innovations respond to local/individual needs, and based on awareness about local context, and raw materials. Many innovators rely on locally available scrap (waste) materials to do these innovations.[17] This does reduce costs, and therefore, the (financial) uncertainties associated with the failure in the innovation efforts. However, the use of scrap has also been motivated by the awareness of locally available devices and technologies, upon which these innovations are predominantly based. The search for appropriate scrap in this case comes as the default first step in the innovation process, and not a fall back option. It is, however, difficult to control the quality of such 'scraps', making reproduction of these innovations often a strenuous task. Note, that reproducibility, with consistent quality, is often a prerequisite for the grant of IPR.[18]

In addition, the IPR, when granted, may have consequences, which are undesirable from a normative standpoint. Sharma and Kumar (2018) show how filing the IPR required an innovator to replace the locally available raw materials (often scraps) by better/standardised materials. This exercise might raise the cost of the product, putting it beyond the reach of the very community whose needs had inspired the innovation in the first place. Since, filing an IPR often requires collaboration with professional scientists and business units, we have found evidence of IPR reducing the control of the original innovators over his/her innovations, to these industrial units, or the 'experts' (Sheikh, 2017).[19] Innovators are often, reportedly, not much worried about the threats of imitation of their technologies. We found such instances in our fieldwork too. The innovator of a battery-run e-rickshaw is not concerned with somebody imitating his technology in another part of the city. Such indifference is apparently also present, for instance, among artisan-innovators of the Kamukunji metalwork clusters in Nairobi. Even a casual visit would show several tiny units displaying their products next to each other. Obviously, imitation would be easy in such a setting, especially with overlapping skills. Why do they not leave the cluster to initiate their own business in a separate place?[20] From a pure economic rationality point of view, it does not perhaps offer them enough advantage to relocate and find the 'market', unless the product they produce is of substantially different quality. Subsequently, the costs to defy the social and communal norms that guide their participation in such informal economy clusters may override their benefits.[21] In addition, since innovation is a continuous process—and happens through trial and error, observational learning, and interaction—they perhaps see the loss through imitation being outweighed by the gains through reciprocal learning, and interactions while co-locating with peers. Imitation to them, unlike large firms, offers new opportunities of learning and capacity building in the long run. Individuals who can imitate/adapt faster than others often hold a high social status among peers. At times though, they do not think their innovations are 'novel enough' to warrant any protection.[22]

A large part of such innovations take place in non-market contexts too (Neder & Thomas, 2010). Secrecy, in such cases, becomes less important. Bhaduri and Kumar (2011) found that concerns of private appropriation become dominant for Indian grassroots innovators, only if the innovations show commercial prospects. Many of these innovations are conceptualised, however, not with an eye to commercial gains. The joy of creation and/or fulfilling social obligations remains a key motivation for the majority of these innovations.[23] Responsiveness to social concerns, therefore, seems to be the primary concerns in these cases.

Bhaduri and Kumar (2011) make an attempt to understand the extent to which innovators discuss their projects with people around them. Only a handful of them reported having such discussions. However, the reason for non-discussion was not to protect their intellectual property or the threat of leakage. Many of them restrained from discussing their projects with others either due to non-availability of suitable persons or due to the fear of being ridiculed at. Indeed, in India, until very recently, such local innovators had rarely been given much social recognition. They would get the recognition in their neighbourhood only when they are able to demonstrate the usefulness of their innovations.[24] Such social apathy to local-level innovative efforts creates undesirable barrier to, following the RRI parlance, stakeholder engagement.

When such social apathy does not exist, or the innovators enjoy the confidence of the society, we find multiple kinds of interactions between the innovators and the society. Kumar (2014) finds that such interactions take the forms of informal but positive ties with the members of their family and/or community. Demand from small farmers in Harare, Zimbabwe, has been found to have shaped manufacture of de-haulers by farmer groups themselves (Manyati, 2014). Sheikh (2017) found that innovators distributed their innovations to the fellow members in the community, free of costs, to receive feedback, which helped them modify and upgrade their designs and processes. Similarly, revival of traditional community knowledge and providing employment opportunities were some of the core concerns, which shaped the innovative efforts towards 'Mitticool'.[25]

A young entrepreneur of a social enterprise producing smokeless stove in Kenya, for instance, boasts of their strong interactions with the local community as the most important source of their competitive strength.[26] However, his familiarity with the local requirements made it difficult for him to get a 'scientific validation' of his products from the regulatory agency. For cooking stoves to be safe and effective, the regulation wants the maximum heat to be retained within the container. On the other hand, the users require this heat be emitted from the stove to keep the household warm, creating a tension between regulatory norms and the societal preference. The dilemma arises because conforming to the scientific standards might give them improved market opportunities elsewhere while depriving the local community of their aspired stove. Several grassroots innovations documented by the India's NIF reveal such dilemmas where innovations which fulfil the local needs fail to conform to the standards of regulatory agencies or scientific institutes. Understandably, therefore, creating an appropriate policy space for such innovations remains a daunting task and an ongoing challenge.[27]

Some Key Normative Implications

Frugal innovations by the vulnerable, essentially, represent an alternative, bottom-up perspective to the discourse on development (Bhaduri, 2016). At the most abstract level, these innovations validate the knowledge of the people on the margin, conventionally seen as mere recipients of technology and knowledge made by 'the experts'. The pursuit of these innovative efforts is mostly in response to societal needs. Thereby, the fear of undesirable *social* consequences for these innovation might be less critical. The possibilities of unintended (negative) technological consequences are also limited, due to several reasons. The first and, perhaps, the most obvious reason is the incremental nature of these innovations, which makes their consequences more detectable. The small scale of production and innovations could, in addition, prevent large-scale undesirable consequences to the environment and the society, making the 'Collingridge's dilemma' redundant. The continuous interaction with (and dependence on) the society perhaps acts as a safeguard against going too far against the interest of the society. Finally, its contribution to sustainability remains notable. Through use of scrap and by emphasising on repairing, it postpones 'planned obsolescence', and helps reduce the threats of technological waste. Several innovative efforts also explore potentials of the various alternative sources of energy, contributing to sustainability efforts at the local levels.[28]

We have mentioned earlier that including laypersons in the decision-making process of the experts remains a key aspiration of RRI scholars. The insights from the frugal innovations by the vulnerable may strengthen the justification for the need for such inclusion. The recent scholarship on the history of innovations (Godin, 2008) and technological changes during the industrial revolution (Mokyr, 2017) too point out the important role played by the laypersons in innovative activities.

Does Frugality Meet Responsibility?

We now analyse how frugal innovations could meet the criteria of responsibility in its innovative activity. As noted earlier, we would explore the meeting points around the four dimensions of RRI, namely anticipation, reflexivity, inclusion and responsiveness. We take each of the four dimensions of RRI and analyse how, and to what extent, the frugal innovations by the vulnerable adhere to these concerns.

Anticipation

As discussed in earlier sections (the third section), the incremental nature and small scale of frugal innovations make them less threatening towards the goals of sustainability. The situations of unintended adverse consequences can be arrested by discontinuing its use, without incurring substantial costs to the socio-technical systems they are entrenched in.[29] In contrast, such costs

could be substantial for large-scale innovations because of the difficulties in reversing/discontinuing the innovation in use, when evidences of their harmful consequences get surfaced (Ribeiro et al., 2018).[30] The difficulty to detect potential adverse consequences at an early stage arises also because these innovations are undertaken in the confounding environment of a laboratory. The subsequent scaling up and transfer of these technologies to the new environment(s) of their *actual* use is far from frictionless. The actors too change, as the technology moves out of the lab to production, and to the market. *Anticipation* of adverse consequences for the actual context is, therefore, inherently difficult at the early stage of these innovations. For bottom-up frugal innovations, on the other hand, such problems in anticipating adverse consequences could be less serious, since these are conceived and undertaken in the actual environment of their use. The people who undertake such innovations are also the first users, making them more *responsive* to the risks and the '*unintended consequences*'. The small scale of production and use makes it easier too to arrest negative consequences, once revealed, overriding the concerns of the 'Collingridge's dilemma'.

Reflexivity and Inclusivity

The kind of *reflexivity* that is expected from the scientific community (discussed in the second section), in order to conduct RRI is quite different from what is observed in our frugal innovation arena. These innovators are reflective of the needs prevalent in their immediate vicinity, and they try to solve the issues using local resources (the third section). They often take a pragmatic approach to these solutions by emphasising on using their familiarity with the local conditions and locally available raw materials. The narratives around these innovative activities might not be loaded with explicit moral and ethical underpinnings, yet guided by their innate desire, and the various societal norms and expectations. This is, however, not to deny that at times these innovators could also be guided by their own personal interests and aspirations. The adverse societal consequences of such desires and interests, if any, would, nevertheless, be limited due to the small scale of operation. [31]

Note that the funds for these innovations are either one's own or arranged through informal networks. Generally, such credits come with 'unlimited liability' (often intergenerational in nature). It is likely that the innovator would in such cases be more cautious in using funds than people who have access to (formal) credits with 'limited liability'. This lack of opportunity to spread the risks in our view might promote judicious spending of money.[32]

The scope of *reflexivity* and *inclusivity*, however, are often limited by the lack of social appreciation of such innovative efforts. Ironically, there often is little recognition of their work by fellow community members, even though solving societal problems remain at the core of these activities. These innovators do not command much respect and admirations, unlike the mainstream scientists at least

in the early stages of their innovation. This hampers the continuous feedback between the innovators and the community. Their work, at the same time, does not get much appreciation from the scientific community, regulators or the mainstream innovators either.

Responsiveness

Finally, the overall *responsiveness* of a frugal innovative activity (measured as an outcome of efforts towards transparency, inclusiveness etc.,) does not lead to the making of new regulations, or standards, as envisioned in the RRI scholarship. However, one can find the trace of such responsiveness in terms of the practical, easily revocable, small-scale, innovative efforts to 'solve' societal problems in the 'actual environment'. It bears particular importance in the absence of credible alternatives from either the State or the market.

Conclusion

The article aims at exploring a space for dialogue between RRI and frugal innovations to frame the possible pathways of future research and policy deliberations. Such a dialogue in our view would help broaden the scope of the discourses on RRI and frugal innovations. Currently, the empirical research on RRI faces a deadlock in terms of living up to the expectations of its theoretical promises. Similarly, with its increasing preoccupation with a product-oriented approach, frugal innovation discourses have sidestepped some of its original goals, such as thrust on reuse of materials, sharing economy and flexibilities in innovation organisation (see Radjou & Prabhu, 2015). Over time, the discourse has become sharply divided into two streams, one focusing on large firms endeavour to cater *to* the Bottom of Pyramid (BoP), while the other (minority) view trying to generate research and policy momentum to investigate the nuances of innovative activities *at* the BoP. The present article, built around the second category of frugal innovation scholarship, examines how a dialogue between frugal and responsible innovation discourse may take shape.

The use of the word 'responsible' has opened up newer possibilities of dialogues within the larger field of innovation studies. We find that the broader ethical underpinnings of RRI in terms of 'transparency, interaction and mutual responsiveness' to ensure inclusivity could be visible at the sites of the frugal innovations by the vulnerable too.[33] These activities also provide a more concrete understanding of the alternative intellectual property management practices that many scholars of RRI insist on. RRI can benefit by including the sites of these local, inclusive, practical and sustainable frugal innovative activities into its ambit. As discussed extensively in the article, these frugal innovations tend to be problem-solving, practical and user driven. They draw their social sustainability implications from their small scale of use and entrenchment in local socio-technical systems. The innovators take a 'satisficing' approach with regard to

their appropriation behaviour, and do not, generally, insist on monopoly creation through IPR, ensuring a freer use or access to these technologies. This is likely to ensure better *inclusion* in the process of development, a key aspiration of the RRI discourse. Although the RRI discourse emphasises on these are often, arguably, difficult to comply with anticipation, reflection and inclusion to be truly responsive, in a large corporate setting. Frugal innovations by the vulnerable groups, being borne out of daily needs, shaped by local resources, and the agency of local people, on the other hand, tend to be inclusive. RRI's mandate is global in nature. The experiences from the sustainable development discourses have taught us the need for complementarities between such global goals and local level actions. Frugal innovations by the vulnerable groups is one such local adaptive mechanism to the problems of scarcity and poverty, that might help achieves these goals. A coherent synergy between these two strands of innovation scholarship may, therefore, be helpful in framing the future development pathways. All this, as Ribeiro et al. (2018) argue, might help better 'social alignment' of RRI.

Admittedly, RRI scholarship pays a much careful attention to study innovation processes than what the scholars on frugal innovations have achieved so far. A deeper engagement with the RRI scholarships might make the scholars of frugal innovations more sensitive to examining innovation processes in general. In this way, the discourses on frugal innovation could come closer to the ideas of 'frugal' and 'frugality' envisaged by Adam Smith. Coming to the specific case of frugal innovations by the vulnerable, an engagement with the RRI might help motivate the innovators, funding agencies, regulatory bodies and the civil society to strengthen their interactions to generate public awareness and debate about the need for a rethinking on policies of appropriation and standard-making. Currently, the innovations by the vulnerable groups remain 'below the radar'. With the rising number of such innovators, there is a need for government intervention to facilitate these innovations, through creation of equitable knowledge-sharing platforms, funding opportunities, awareness, etc. States could collaborate with the civil society in the framing of responsible regulation that is sensitive to the needs of the actors 'on the margins'. All this has the potential to reshape the processes of such innovations by including more diverse actors.

Scale of such innovations remains a sore point. While a very large scale may dilute the context specificity of these innovations, their current very small scale of operation may also need a rethink. The involvement of new actors, motivated by the broader ethos and mandates of RRI, can inject new thoughts into the possible pathways of scaling up such innovations without diluting the core concerns of context specificity of these innovations and their societal control.

Finally, we have noted earlier that frugal innovation research has, over time, sidestepped some of the core concerns of its founding scholars, namely the thrust on reuse, sharing and flexibility in organisations. Incidentally, the innovative activities by the vulnerable seem to remain aligned to these concerns. A renewed mandate, to be *responsible*, might help bring these concerns back into the agenda of frugal innovation research.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

FUNDING

The authors disclosed receipt of the following financial support for the research, authorship and/or publication of this article: The data and observations on Kamakunji cluster (Nairobi) and Dindigul cluster (Tamil Nadu) were gathered during a fieldwork by the first author funded by the Prince Claus Chair Curatorium, The Netherlands.

NOTES

1. Several scholars are working towards this objective of reframing RRI. See, for instance, Pandey (2016).
2. Acceptability (ethically), sustainability and social desirability here, however, is mentioned in the context of European Union's (EU's) charter on fundamental rights and the normative points of the treaty of the EU.
3. Reflexivity could be brought about by multidisciplinary collaboration and training, presence of social scientists and ethicists in laboratories, ethical technology assessment, codes of conduct and moratoriums.
4. What they mean by alternative intellectual property rights however remains, unexplained.
5. In cases of apparent high risks to health or environment, regulation making is expedited or precautionary principles are applied. Note, however, that the remedial effect of regulation would depend on whether it has been able to include the concerns and interests of the marginal social players affected by an innovation. Often, regulatory capture by big players can influence the regulatory decision-making to keep such voices below the radar.
6. Bhaduri, Sharma, and Talat (2015) argue how water purification technologies in India evolved in a regulatory vacuum for a long time, allowing path dependencies of certain technologies with probable deleterious effects on health and environment to get established (Talat & Bhaduri, 2017). Such delays in regulatory responses might make it difficult to undo the negative effects completely.
7. Horizon scanning refers to a range of web-based approaches for identifying emerging issues/ opportunities, associated impacts, risks and benefits, etc., by scanning the emerging literature (e.g., scientific, peer-reviewed or otherwise) and then synthesising this through knowledge management approaches (Owen et al., 2009).
8. Such decisions, however, are rarely inferior to the decisions made by experts using logic and optimality-based decision rules.
9. One can find two strands in this scholarship. While one strand talks, exclusively, about innovations by the poor and the marginal (Bhaduri & Kumar 2011; Gupta, 2016; Sheikh, 2014), the other strand finds it less important to distinguish between innovations for the poor and innovations by the poor, and, often, club both as grassroots innovations (Smith, Ely, Fressoli, Abrol, & Around, 2016). Both the streams, however, emphasise on 'non-state' actors in shaping these innovations.
10. These nomenclatures are still evolving, with diverse meanings and interpretations. See Cozzens and Sutz (2014) for detail. All these innovations, however, aim to solve the local problems of livelihoods by the people on the margin.
11. This makes it difficult to overlook its connection to frugality, as envisaged by Adam Smith (1776) and Gigerenzer (2008).
12. Sympathetic outsiders, here, refer to the agents who are considerate towards the activities of frugal innovators, appreciate them and help them in their process of innovations.

13. It is important to mention here that the goals of affordability and sustainability are inherent to both types of frugal innovations (Radjou & Prabhu, 2015).
14. India's National Innovation Foundation (NIF) is trying to bridge the gap.
15. However, the 'do it yourself' movements or the so-called 'Proof of Concept' (PoC) movements (or hacker's space) are also some of the manifestations of frugal innovations, occurring in the Global North.
16. Private appropriation of knowledge through securing intellectual property, secrecy or lead time is used by the industry, government institutes and universities, across the globe.
17. 'Local' here does not fall into the binaries such as traditional/modern, natural/mechanical. The rural settings in India (and elsewhere) are far more complex and have considerable overlaps with the urban areas in terms of production and consumption behaviour. Local skills, raw materials and knowledge, therefore, constitute a 'complex overlapping whole' of these binaries.
18. Perhaps the field of genetic engineering is an exception.
19. Adrian Smith and his colleagues have studied many cases where the local communities have resisted losing control of their innovations to either big commercial units or to the State (Smith, 2014).
20. Leaving such clusters, however, is not altogether absent among informal sector artisans. The lead author found one such instance in the hand-made lock cluster in Dindigul, Tamil Nadu, India.
21. Sheikh (2014) found presence of communal appropriation mechanisms among the weavers of Pashmina Shawl in Kashmir through the usage of codes.
22. A study by the World Intellectual Property Organization seems to also share such a finding. See, for instance, http://www.ip-watch.org/2014/06/03/innovation-occurs-in-informal-economy-needs-policy-framework-panellists-say/, for detail. Note that adaptability is an important dimension of frugality as in Gigerenzer (2008).
23. It is perhaps worth recalling that joy of creation as a major motivation behind innovation is acknowledged even in the mainstream theories of innovation, à la, Schumpeter. In his *Capitalism, Socialism and Democracy*, Schumpter recognises that gains to private property can explain only a part of motivation behind innovative activities. In his view, 'the joy of creating, of getting things done' to 'seek out difficulties … and takes delight in ventures' are integral to innovation and economic development (Schumpeter, 1934, pp. 93–94).
24. Their immediate family members, however, remain in know of their doings, except in rare circumstances.
25. Although the immediate driver was a natural calamity in the locality. See https://www.thebetterindia.com/14711/mitticool-rural-innovation-nif-mansukhbhai/
26. Personal interaction at the Seminar on Grassroots Innovation organised by the International Institute of Social Studies (ISS), Partos, the Prince Claus Chair and the Centre for Frugal Innovation in Africa (CFIA) on 21 November 2017.
27. Interested readers might consult Bhaduri (2016); the discussions on the web platforms of POC21, the network of Developmental Outcomes of Local Innovations and the India's NIF.
28. NIF features several such innovations such as Power Generation through Sewage/Slow Moving Water (http://nif.org.in/innovation/Power_generation_-through_-sewage-slow_-moving_-water/49), Energy Conservation in Agricultural Pump Sets (http://nif.org.in/innovation/Energy_conservation_in_agricultural_pump_sets/105) and Energy Generating Shoes (http://nif.org.in/innovation/Energy_Generating_Shoes/216).
29. There are several instances to support this argument. In pharmaceutical and medical device industries, such unintended negative consequences have not only led to financial loss to the firms but also inflicted major societal loss in the forms of deaths and disability.
30. Private firms, in such situations, may have reasons to behave opportunistically in order to hide the negative consequences.
31. The issue of appropriate scale for such innovations remains a sore point, and one of the most common questions we have faced during our conversations with experts within and outside the academia. While a detailed discussion is beyond the scope of the current article, it might suffice to note that

the emerging scholarship on degrowth too insists on a conflicting relationship between scale and sustainability. Clearly, this issue requires further research from multiple disciplinary backgrounds.

32. Indeed, limited liability originated to provide entrepreneurial opportunities of risk-taking. Such judiciousness once again echoes the spirit of frugality, as in Smith (1776, p. 247).
33. May be more prominently than that in the large business organisation.

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Constructing Alternative Socio-technical Worlds: Re-imagining RRI through SRI in India

C SHAMBU PRASAD

While Responsible Research and Innovation has the potential for democratising the governance of research and innovation, translating it in the Global South would need dialogues and engaging with the plural knowledge systems and ongoing experiments on innovation at the margins that seek to construct alternatives. Entrenched power relations in the South do not allow for public dialogues that allows for society to engage with, if not speak back, to scientists in co-creating newer knowledge. Through the case study of the System of Rice Intensification (SRI), an agroecological innovation that arose outside the formal research establishment, we show how vulnerable farming communities can proactively co-create alternatives to existing dilemmas in Indian agriculture. Re-imaging RRI in India, we suggest, requires closer attention to the role of civil society organisations in creating innovation spaces through informal and heterogeneous networks of social learning. Networks, we suggest, allow for better expression of creative dissent that could open newer vistas and alternative framing of knowledge. The RRI agenda is thus incomplete without an engagement with the politics of knowledge, and scientific controversies reveal technological lock-ins that hinders alternative framings and pathways.

Keywords: Creative dissent, networks, knowledge politics, SRI, RRI

Responsible Research and Innovation (RRI) is an emerging area of interest for both scholars of innovation management and science and technology studies. RRI presents opportunities for democratic governance of research and innovation towards 'right impacts'; responsiveness through designing institutional processes that could make innovations socially acceptable and enables the framing of responsibility towards greater collective activities—'science for and with society' (Owen,

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Science, Technology & Society 25:2 (2020): 291–307
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820903002

Macnaghten, & Stilgoe, 2012). Rip (2014) sees RRI as a discourse and an emerging patchwork of practices which creates opening in existing (and evolving) divisions of moral labour. As a process, the RRI framework includes anticipation (of futures), reflexivity (of researchers and innovators on the effects of their work), inclusion (of relevant stakeholders) and responsiveness (to the needs and ambitions of society; Stilgoe, Owen, & Macnaghten, 2013). Most RRI literature has been from the European Union. RRI is an aspiration but also an explicit programme to connect societal challenges with research goals and questions in the Netherlands. There have also been some cases of transatlantic dialogues in the domain of nanotechnology.

This article explores the potential of RRI in the Global South (the two-thirds world) and in agriculture where it has been insufficiently studied.[1] As an emerging field of the twenty-first century, there is a case for a dialogue on RRI with scholars from the Global South. Governing agricultural innovation in India is both complex given the large and diverse kind of stakeholders and inherently plural with different and differing views on innovation. I argue, through the case study of an agroecological innovation—the System of Rice Intensification (SRI), that while the aim and aspiration of a new social contract of science through RRI is welcome, there is a need for RRI to be more than a knowledge management exercise. It requires an awareness and engagement of the structures of power that exclude alternative knowledge systems. We need to also ask as to how inclusive and reflexive are scientific agencies? Would a mere prescription of a framework of responsibility and responsiveness suffice or would researchers have to go deeper into examining the politics of knowledge and the structures that disable inclusion? Given the complex and messy nature of innovation, how can RRI in the Global South be reframed to enable designing inclusive processes and innovation spaces for knowledge dialogues? Should the governance of innovation also include mapping and seeking alternative framings in what Bijker (2017) proposed for 'constructing worlds'?

In the first part of the article, I explore the RRI dimension of anticipation by looking, in the anticipation of futures, at the Indian innovation paradox. The metaphors and processes of envisioning futures, have in India, privileged the scientific or technocratic expert and excluded alternate visions or perspectives. Vulnerable farmers, disenfranchised by the scientific community, have been among the front runners advancing RRI. This has implications for both the dimension of deliberation in RRI. I suggest that India needs to take its innovations at its margins by farmers or civil society organisations seriously.

In part two of the article, I explore these questions through the innovative, turbulent and messy journey of an agroecological innovation, the SRI in India. I examine the challenges in a sustainable transition from the dominant input-intensive Green Revolution (GR) paradigm to the knowledge-intensive agroecological paradigm. Agricultural research institutions in India have been shaped by the GR paradigm that has been credited with making India food secure in the 1970s. Depleting soils, plummeting groundwater reserves and a significant loss of crop diversity and its excessive focus on certain regions have led to neglect and exclusion of farmers in 'unfavourable' regions. Paradoxically, these vulnerable farmers are now seen

at the forefront of innovations in agroecology even as the scientific establishment seems locked-in to conventional pathways. Responsible innovation needs to map the global politics of knowledge that could be a big impediment in this process of sustainable transformation. In presenting an alternate paradigm of innovation, SRI researchers have reworked the idea of responsibility by presenting alternative narratives when confronted with a powerful scientific establishment that is focused on the gene revolution. These 'facts', as the SRI case would show, are to be sought and scoped for more proactively at sites of collective experimentation and innovation spaces. In this exercise, I argue using an STS perspective that scientific controversies rather than being shunned need to be explored as useful sites for revealing the uncertainty of science. Opening up the 'black box' through a critique of the dominant narrative creates opportunities to open up knowledge dialogues.

This process of deliberation that includes contestation has implications for research programmes and research policy, which I explore in the third part of the article on governing innovation. A proactive RRI should allow, and even push for, inclusive processes of reframing of agendas, and not just make science accountable to society but make it to work through constructing socio-technical worlds. Newer technological cultures could be built through examining and building alternative narratives (Bijker, 2017). In creating and enabling an international network of researchers, the promoters of SRI not only open up the debate on SRI but also present newer possibilities of responsibility for Indian agricultural researchers. The SRI case is thus not one single story of responsible innovation but of several narratives of change that push us to rethink and reimagine RRI as a knowledge dialogue on science and democracy.

Anticipating Innovation in India: The Inclusion Challenge

Innovation that was earlier seen as peripheral to larger science and technology policies is now central to a mission-driven project aimed at 'Reinventing India as an Innovation Nation'.[2] Innovation in India is imbued with multiple meanings and metaphors. New phrases such as 'frugal innovation', 'jugaad' and 'reverse innovation' have entered the innovation management lexicon (Birtchnell, 2011; Govindarajan & Trimble, 2013; Kumar & Puranam, 2012). Beyond the buzzwords and the aspiration to become an innovation superpower, India also faces huge challenges of inclusion and equity. An uncomfortably large number of vulnerable Indians—tribals, peasants, artisans—arguably the largest numbers in the world, who practice, access and are serviced by indigenous knowledge systems are not part of this innovation story. Unlike the Global North that has little living memory of indigenous knowledge; in India practitioners of indigenous knowledge compete, negotiate and innovate both against and with modern scientific knowledge. They offer counter-narratives to the larger, mainstream, nation state narrative on innovation. Anticipating future and governing innovation, key elements of RRI, need to appreciate this plurality of knowledge systems.

Official Indian policies such as India's science, technology and innovation policy (STIP, 2013) or Technology Vision 2035 (TV 2035)[3] have visions of the future, but have surprisingly little to say on social innovation, sustainability or notions of responsibility in innovation. Policy documents see innovation in a linear way and privilege the know-all technical expert who would deliver solutions to the 'lay' citizen seen as lacking knowledge. Public participation in science and technology policy is significantly lower than other domains (Prasad, 2008). The role of civil society as knowledge intermediaries is recognised in RRI, but public policies in India tend to delegate civil society's role to the bottom of the innovation chain in seeking to disseminate innovation rather than regarding them as partners in a search for newer models of 'inclusive innovation' (Bound & Thornton, 2012; Prasad, 2005). Of the twenty-four names listed as key contributors to TV 2035, only two were from outside the formal S&T architecture of the country in a particularly applied vision on food and agriculture. The agency of citizens and of 'other' knowledge systems is conspicuous by its absence in a vision created by the techno-scientific bureaucracy (Sekhsaria & Thayyil, 2017).

Unlike the Global North, existing power relations in India do not allow for public dialogues that allow for society to engage with, if not 'speak back' to scientists in co-creating newer knowledge (Gibbons, 1999). Translating RRI in the Global South needs to take cognisance of such dissonances and explore alternate visions of the future. As an aspiration for more democratic innovation governance, ideas of RRI resonate with a few experiments in rethinking and re-imagining science-society relations as conversations on science and democracy (KICS, 2011). The deliberative dimension of RRI in the Indian context needs to account for this complexity. As the case shows, responsible innovation occurs through innovation spaces for creative dissent within the scientific establishment and having knowledge dialogues that allow for informal and heterogeneous networks of social learning. A mere meeting of stakeholders would not lead to deliberation unless this is preceded by an exercise that maps and allows for the articulation of diverse ideas and discourses.

Vulnerability and Innovation in India

Agriculture in India is beset with paradoxes. India leads world production of milk and buffalo meat, is second in wheat, sugar, fruits and vegetables, and paradoxically also leads the world in number of farm suicides. Over 270,000 farmers committed suicide in the last fifteen years, more than half of them (52%) continue to be indebted (Dandekar & Bhattacharya, 2017). While productivity initially increased, farm incomes have stagnated or declined. A wave of farmer protests have emerged across the country in 2017–2018 with farmers demanding loan waivers as they face increased costs and declining incomes due to depressed commodity prices, and high variability and unpredictability of weather.

The GR significantly changed the production landscape in India. Punjab and Haryana that were marginal to rice cultivation in India became the new rice bowls producing low-value rice procured by the government for its buffer stock and

distribution. The ecological costs of the GR paradigm that was premised on input-intensive agriculture of a few cereals, rice and wheat, in favoured regions can no longer be ignored.[4] India *is the world's largest consumer of groundwater* (210 billion cubic meters), 89 per cent of it is used for irrigation. Poor quality and groundwater shortage is experienced in more than 60 per cent of districts in India (Shah, 2013). Fertiliser subsidies in India not only cost the Indian exchequer vast amounts of money but are skewed in favour of irrigated areas and a few crops (Rupela & Gopikrishna, 2011). Recent estimates indicate that small and marginal farmers (who are over 85% of all farmers) received only about one-third of the total subsidy on fertilisers and less than 50 per cent of agricultural credit (Subramanian, 2017).

Fast-changing agrarian relations in the countryside means that even if farmers managed access to inputs over a period, this has led to high dependence on newer 'merchants of knowledge' or petty retailers at village level for credit, technical knowledge and even sale of their product (Aga, 2018). Indian farmers are experiencing a loss of agency, 'agricultural individualisation', and 'knowledge dissonance' (Vasavi, 2012), and deskilling (Stone, 2007). This knowledge dimension is less understood and discussed on India's agrarian crisis. The response of the Indian agricultural establishment to the agrarian crisis has oscillated between denial and techno-fixes. For instance, in rice while it is acknowledged that yields have stagnated after the GR, the rice research focus has been predominantly on irrigated rice. Unfavourable (or rainfed) environment in rice research has been underinvested (Pandey & Pal, 2007). Recent course correction through a greater focus on the eastern region has been less than innovative. Schemes like 'Bringing Green Revolution to Eastern India' (BGREI) only extend GR with little discussion on the knowledge aspect or any engagement with vulnerable farmers as stakeholders.

In contrast to the input-intensive strategy of GR, there has been a movement for agroecology that seeks to reclaim the agency of the farmer and highlight the sustainability imperative and the need to move away from existing GR-based technologies and food systems. Agroecology—defined as 'the application of ecological concepts and principles to the design and management of sustainable agro-ecosystems' (Altieri, 1995)—draws from ongoing food sovereignty and ecology movements, and presents an alternative paradigm and narrative of change that is knowledge-intensive. Agroecological methods provide greater environmental sustainability and enhance the resilience of farmers by reducing their dependence on costly and sometimes difficult-to-access chemical inputs. There is increased overall productivity through a diverse range of agricultural products and environmental services, and reduced risks of crop failure (Pimbert, 2018; Silici, 2014).

Agroecology is not a recognised knowledge frame in India by the research establishment and thus despite the widening spread of practices that go under different names—Non-pesticidal Management (NPM) that later got reworked as Community Managed Sustainable Agriculture (CMSA), Zero Budget Natural Farming (ZBNF), SRI or its adaptation to crops other than rice or System of Crop Intensification (SCI)—they have largely remained outside mainstream research and extension agencies (Khadse, Rosset, Morales, & Ferguson, 2018; Prasad

et al., 2015). Most agroecological practices draw upon farmers' knowledge but work with modern scientific knowledge of agronomy, entomology, soil-microbiology, etc., in interesting ways and thus are neither 'traditional' nor 'modern'. SRI is one such agroecological innovation and is the case that we take up for discussion here. We show how a newer paradigm that lays emphasis on farmer and collective experimentation can actually enable vulnerable farmers to innovate and reclaim control of their lives and lands.

Constructing Worlds: SRI and the Green Revolution

The GR paradigm has shaped the institutions of agricultural R&D since the late 1960s with a focus on productivity and increased food supplies. It is now accepted, even by erstwhile champions of GR like Swaminathan, that this strategy has several long-term adverse effects (Kesavan & Swaminathan, 2018) with declining returns, reduced farm income, nutritional imbalance and adverse environmental impacts. SRI, in contrast, presents an alternate, even counter-intuitive, paradigm for rice farming. Through innovations in agronomical practices (rather than genetic improvement) and changes in the management of rice plants, soil, water and nutrients, SRI principles enable the emergence of more productive and robust phenotypes. These principles translate into a set of practices that differ considerably from conventional rice cultivation techniques and involve transplantation of young seedlings, widely spaced, in unflooded but moist soil conditions, and involve the greater use of organic matter in soil, and a hand or motorised weeder for weed control which also aerates the soil surface. SRI contributes to the three pillars of climate-smart agriculture by increasing productivity, farm livelihoods and food security; helping farmers adapt to and increase their resilience to the impacts of climate change; and mitigating greenhouse gas emissions (Styger & Uphoff, 2016; Uphoff, 2017).

As an innovation story, SRI is a messy and complex one with its slow evolution in remote Madagascar by Henri de Laulanie, a Jesuit priest and agronomist, in the 1980s. It was unknown to the rest of the world until 1999. Due in large part through the efforts of the political scientist, Norman Uphoff, then Director of the Cornell International Institute for Food Agriculture and Development (CIIFAD) and his working with and through networks of civil society organisations, researchers and policymakers, SRI has spread to more than fifty countries of Asia, Africa and Latin America. While seed funding from CIIFAD helped initial spread, the innovation has largely been possible through the entrepreneurial energies of a small and lean team at Cornell, later SRI Rice.[5] Its origin outside the formal scientific establishment and the claims of yield in excess of what was considered the biological maximum pitted it against the International Rice Research Institute (IRRI) and much of the rice research establishment leading to scientific controversies referred to as the 'rice wars' (Prasad, 2006). Despite the controversies, it has been adopted and adapted by an estimated 10 million farmers across the globe to crops beyond rice.

As an innovation, SRI has evolved through multiple actors. The framing of SRI, from the very start, has been not as a technology or practice but as an agro-ecological movement with deep commitment to sustainability and a vision of natural systems as 'open systems' (Uphoff, 2017). This framing carries notions of responsible research presenting an alternative 'narrative of change' to the strategies and narratives of yield enhancement. Another dimension of SRI as a responsible innovation was in it being presented as 'open source' and non-proprietary knowledge from the outset, thereby ensuring free access by farmers and researchers to the new ideas and opportunities. As SRI practices involved no miracle seed or herbicides for improving productivity, resource-poor farmers, first in Madagascar and later in other parts of the world, were encouraged to draw on their own potential for experimentation instead of expecting and letting commercial interests drive and dominate agricultural innovation. This helped diverse actors from India access and improve upon the innovation.

SRI's entry, and subsequent spread, in India since 2000 exemplifies the multi-institutional character of the innovation as an RRI with an active role played by civil society organisations in shaping the innovation. Civil society organisations, we suggest, mediate different kinds of knowledge and also co-create them. Table 1 summarises the nearly two decade innovation journey of SRI in India under five phases.

SRI was simultaneously introduced by researchers and CSOs in 1999–2000, but initial results were not spectacular. Open innovations allow different actors

Table 1
Various Phases of SRI as RRI in India

Period	*Characteristic of Responsible Innovation*
1999–2003	'Experimentation' by civil society actors and researchers in South India; drought as an important trigger for initial SRI research, emphasis on water saving.
2004–2006	'Gathering evidence on SRI, building momentum'; multi-locational trials by Indian researchers challenge the notion of SRI as a 'niche' innovation as indicated in the 'rice wars'. WWF emerges as key player, organises first of its kind multi-stakeholder national SRI symposium in 2006 (Hyderabad).
2007–2009	'Diversification and reframing'; spread to poorer regions, greater small farmer and food security rather than water saving focus. Newer dimensions of the innovation climate-change resilience, and SRI effectiveness with indigenous varieties emerge from margins; National symposia in 2007 (Agartala) and 2008 (Coimbatore); Several state-level SRI workshops.
2010–2014	'Institutional challenges in mainstreaming SRI': Policy dialogues to 'mainstream' SRI evoke little interest from agriculture ministry though Department of Rural Development. Through its state livelihood missions, bring in scale and a livelihood and pro-poor focus; robust experimentation with SCI-SRI methods to other crops such as wheat, finger millet, sugarcane and mustard. International conference on SRI with Wageningen University and Research & NCS.
2015–2018	Evidence of India's global leadership in SRI increasing, but not reflected in research policy and priorities. SCI reaches scale in remote rainfed areas, especially in millets, wheat, etc.

Source: The author.

and users to imbue multiple meanings to an innovation and enable its spread in diverse ways (Prasad, 2006). Wide experimentation by CSOs and farmers in Andhra Pradesh led by World Wide Fund for Nature (WWF), India, based at International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) provided a spur to SRI from 2003–2004.

In the second phase of SRI in India, WWF played a proactive role in gathering evidence and providing momentum to the innovation. WWF later funded various collaborative workshops and experiments in research and extension, first in Andhra Pradesh and later in different parts of the country. In a significant institutional innovation, it created an innovation platform, the National Symposium on SRI in 2006, rare in the Indian context that opened the research agenda to farmers and CSOs who engaged in knowledge dialogues with scientists and administrators. Institutional innovations complemented the technical innovations and experiments on SRI, and Indian researchers started contributing to the global pool of SRI knowledge.

A significant shift in the innovation happened with a change in location. Spurred by a field visit to the rice fields in Tripura in Northeast India, where SRI had gone to scale in a state that had no agricultural university or strong research centres unlike Hyderabad, WWF and its partners conducted the 2nd national symposium at Tripura in 2007. States that were not part of the earlier GR such as Bihar, Odisha, Uttarakhand and Tripura were now at the forefront of innovation on SRI. SRI soon emerged as a movement of and for small and marginal farmers who were shaping the innovation differently with a greater focus on food security instead of the earlier emphasis on water saving. More women participated too in these states. Newer institutional arrangements such as the learning alliance in Odisha (Prasad, Beumer, & Mohanty, 2007) and state-level workshops in Uttarakhand and Himachal Pradesh democratised the innovation with different discourses that were more locally rooted (Prasad, 2015).

Despite its spread, there were significant challenges in institutionalizing or mainstreaming the innovation within Department of Agriculture due to the scientific controversy on SRI. Interestingly though, state Department of Rural Development in Bihar, Jharkhand and Madhya Pradesh took up SRI through rural women's self-help groups and brought in a livelihood rather than a productivity focus to the innovation. While there was some traction with a few policymakers, leading to dialogues with Planning Commission members and to the formation of a subgroup to formulate ideas for upscaling of SRI, national research centres continued to be sceptical and often pushed back against SRI protagonists by invoking doubts voiced in the 'rice wars'. An informal alliance known as the National Consortium on SRI (NCS) continued to push the agenda forward by bringing newer information and data onto the table, continually seeking to engage policymakers and pointing out opportunities for India to be an international leader in this area, as close to 40 per cent of all journal articles published on SRI currently are from Indian researchers (Prasad, 2016).

The above developments in SRI in India indicate a dynamic and diverse journey by multiple actors. Notably, there is no single organisation that has singularly led all

the developments over the years and across locations. On the contrary, the complex interplay of actors has been facilitated by their deriving strength from participation in national and international networks and newer forms of spaces for innovation. Acceptance of good or responsible ideas is not as easily achieved through a meeting of actors and stakeholders in a consultative process. Conflict and controversies need to be seen as part of the RRI process, and this surely was the case in SRI.

Scientific Controversies and RRI

High yields reported from some SRI fields in Madagascar that exceeded what established rice scientists considered as the biological maximum led to the 'rice wars' and scientific controversies (Prasad & Basu, 2005). The controversy peaked in 2004 during the International Year of Rice (IYR). *Nature* carried an article on SRI 'Feast or Famine' provocatively subtitled captioned 'Proponents call it a miracle. Detractors call it smoke and mirrors. Will SRI feed the hungry or needlessly divert farmers from tried and true techniques (Surridge, 2004)?' The declaration of the UN General Assembly in 2004 to focus attention on a single crop, rice, was unprecedented, and resulted from the successful advocacy and lobbying by IRRI. Those who already had experience with SRI suggested that most of the aims of the IYR agenda could be met, quickly and with considerably lower costs by following SRI principles.

The controversy was about contrasting world views and played out in different forms in conferences, journals and mainstream media. The critique of SRI was led by rice scientists from IRRI who dismissed SRI as anecdotal, technically flawed and lacking scientific evidence. They were countered by a small set of scientists who argued that field evidence of SRI actually presents an opportunity to rethink agronomy drawing from hitherto ignored research directions that could better explain the SRI phenomenon. As an emerging alternative with significant potential scientists, they believed, should carry out several experiments with SRI to not just find if it works but also seek to discover the 'science' behind SRI and take farmers experiences with SRI seriously (Stoop & Kassam, 2005). The disinterest and subsequent hostility of IRRI scientists though had a lot to do with their lock-ins towards a particular agricultural future.

From a Science Technology and Society Studies (STS) perspective, an exploration of scientific controversies reveal the 'uncertain side of science' (Pinch & Leuenberger, 2006) with scientists commonly using scientific findings with 'interpretative flexibility' (Pinch & Bijker, 1984). An earlier article by Surridge (2002) celebrated IRRI's research direction for a Second Green Revolution that was to involve the 'most audacious feat of genetic engineering yet attempted'. This involved developing a New Plant Type to raise a hypothetical yield ceiling by 25 per cent, or by genetically modifying rice to have a C4 photosynthetic pathway instead of its evolved C3 pathway. Millions of dollars were to be invested as part of a consortium effort that IRRI was leading, and putting this high on the research agenda was part of the IYR campaign to legitimate and mobilise research and

donor funds (Sheehy, Mitchell, & Hardy, 2007). SRI, an upstart innovation from outside established scientific circles, was surely a threat to such intentions. SRI proponents reported that remarkable yield improvements could be achieved with just a fraction of the funds and investments needed for a C3/C4 transformation.

There was a short but intense period of discussions in some of the leading scientific journals on agronomy like *Field Crops Research* (FCR) between 2004 and 2008 on SRI. A close look at the articles—not just at their content but the asymmetry in the way that papers for and against SRI went through the review process—reveals interesting insights into the politics of knowledge. The scientific journal had a rather disproportionate amount of rhetoric deriding proponents of SRI as 'advocates of nonsense' and practitioners of 'non-science' and SRI as a 'curiosity' and 'unverified field observation' (UFO). Discussion on science vs non-science is germane to many social science journals, especially those concerned about the relations between science and society, but it is curious that phrases such as 'non-science', or UFO had never appeared in the journal's history since 1978. For a scientific journal with a high impact factor, it was unusual to see the polemics and rhetoric against SRI. Scrutiny of the articles' histories reveals that articles critical of SRI had an unusually short time from receipt to acceptance for publication (as few as 7 or 11 days). Responses by SRI proponents took many times longer to process (88 days at a minimum).

Internal changes from 2008 onwards indicate more normal review periods. *FCR* has had only two articles on SRI since 2009, and none since 2012. SRI researchers chose to publish in other peer-reviewed journals such as *Paddy and Water Environment*, *Experimental Agriculture* and *Plant and Soil*, which have been more open to research on SRI. The discussion on the politics of knowledge I suggest needs to be seen as part of discussions on RRI. Not all responsible innovations might have such a contested journey, but the narration of the scientific controversy is only to illustrate the challenges of governance of RRI when there are different knowledge systems. In the absence of official support, Indian researchers drew from and contributed to SRI knowledge through participation in international networks. This alternate organisation of innovation and knowledge through newer innovation spaces merits closer attention.

Organising for SRI: Networks and Responsible Innovation

Networks have had a silent, often invisible empowering role for individuals working within established and hierarchical organisations. The connectivity that networks have provided—ideas, critical feedback, personal friendships—have encouraged agricultural researchers to think outside prevailing 'boxes' and to be 'creative dissenters'. They have provided space for conversations across the boundaries of their own disciplines (Prasad, 2016; Prasad et al., 2012). At the international level, SRI Rice has proactively connected SRI enthusiasts across the world. An offshoot of CIIFAD at Cornell University, SRI-Rice has been the main source of information on SRI. Researchers have benefited from the

specialised documentation service on the SRI-Rice website, which provides access to all available SRI articles, databases, thesis and reports on SRI and places them online.[6] SRI-Rice has provided useful support in many ways, for example, by plugging young researchers into informal transnational networks, by sustaining an informal worldwide peer group, and building research capacities and visibility among researchers in developing countries by providing pro bono editorial support and advice. SRI Rice has in turn facilitated and worked with many informal networks and some formal national networks such as that originally led by WWF in India and the NCS, capturing local research that often escapes international databases.

The open-source collaborative architecture of the SRI movement has facilitated the emergence of a new 'knowledge commons' for agriculture, countervailing the currently dominant trend towards proprietarisation of agricultural technology. This has taken diverse forms such as e-groups and regional networks; joint participation in panels at mainstream professional and subject conferences; wide sharing of manuals, videos, and PowerPoint presentations made in different forums; and specialised Facebook pages on equipment. The diversity of these networks induces transformation in knowledge systems and can avoid the kind of domination by researchers in innovation platforms manifested elsewhere (Prasad, 2016).

Research policies and futures in the Global South are often shaped by international trends. Given the size and importance of its rice crop and the large indigenous rice research capacity, India could have chosen a different research pathway organising independent assessments of SRI. However, but for a few scientists, mainstream Indian rice researchers were reluctant to carry out research trials on SRI. One of the responses to the rice wars and the *Nature* article was from Alapati Satyanarayana who in his response presented alternate facts of the SRI trials in the state of Andhra Pradesh ending with an invitation to the international scientific community to engage with the (scientific) issues of SRI.[7]

Changes in settled thinking often require dissonant voices within the scientific establishment who interact with and listen to non-research actors, in the process reconciling diverse experience and translating ideas for paradigm change and sustainability to engage agricultural researchers. Dr T. M. Thiagarajan (TMT), a soil scientist, and the lone Indian researcher to have participated at the International SRI Conference at Sanya in 2002, was one of them who led SRI research in Tamil Nadu. Satyanarayana and TMT opened up research pathways for other Indian scientists to practice 'creative dissent' (Prasad, 2014) by avoiding direct confrontation with the establishment and working silently on SRI. Beyond the scientific controversies in journals, there were several engagements, encounters and dialogues as part of the everyday practice of scientific research (Prasad, 2009).

They were joined by, among other, the soil microbiologist, the late O. P. Rupela, whose trials provided useful insights into the complex below the surface environment that contributes to the SRI phenomenon and Amod Thakur, an agronomist, who was inspired to take up SRI research following the scientific controversy and is the most published researcher on SRI from India. A prominent creative dissenter who gently led and encouraged his colleagues towards knowledge dialogues was the late N. K.

Sanghi who worked proactively with CSOs in pushing for an alternate paradigm for agriculture (Prasad, 2015; Prasad et al., 2012). Despite any clear policy or research programme on SRI, these handful of researchers have been able to work with farmers and CSOs to extend SRI principles, even to other crops. A good example is the evaluation research done on the System of Wheat Intensification (SWI, extending SRI ideas to wheat-growing) at the Indian Agricultural Research Institute (IARI) in collaboration with the CSO Professional Assistance for Development Action (PRADAN) in 2011–2013. IARI scientists and PRADAN brought to Delhi a farmer from Bihar who had practiced SWI. Together they developed agreed-upon research protocols for comparing SWI with IARI's recommended best practices. The farmers then managed the SWI plots accordingly so that the new methods were used properly and the SWI yield advantage was increased to 46 per cent (Dhar, Barah, Vyas, & Uphoff, 2015).

How exactly did SRI research in India benefit and what might be lessons for research policy in India and the world? A detailed look at the research indicates significant surprises and reiterates the need to construct alternate facts.

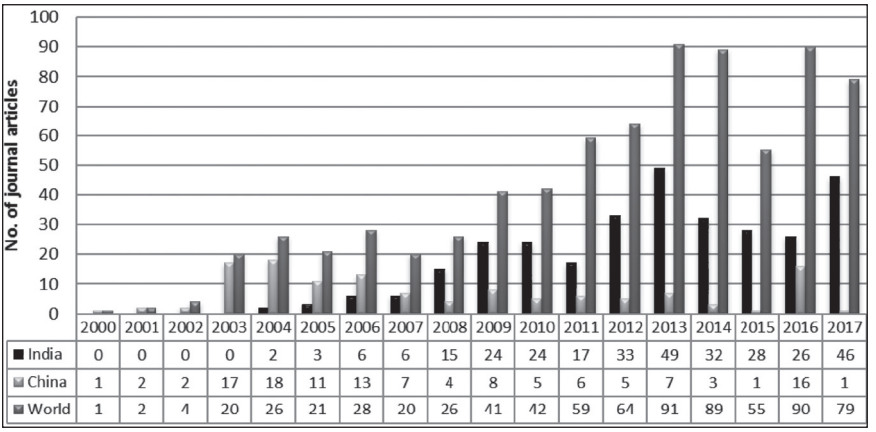
Governing Innovation: India as a Reluctant Leader of Agroecology

In an insightful and reflexive piece on science, technology and democracy, Wiebe Bijker (2017) suggests that STS could be used not just as a critical frame but to help navigate, if not solve, complex societal problems that are also technical. A study of technological cultures, he suggests, needs to include a proactive attempt to construct socio-technical worlds. How can, he asks, STS offer a response to alternative narratives without falling back into naive positivism? Can STS help to make science accountable to society *and* make it work—make it function in our democracies *and* let it produce scientific knowledge?

In this concluding part, we build on this idea further by suggesting alternative pathways for research policy on agroecology in India. By a re-reading of scientific controversy relating to technological lock-ins by the dominant research paradigm in rice and the politics of knowledge has hindered alternative narratives. Vanloqueren and Baret (2009), in their study, have pointed to how existing institutions and the overall organisation of our research systems favour the dominant genetic-engineering research strategy rather than explore and validate agroecological methods. Though their reference was not to SRI, the evidence presented on the politics of knowledge show similar trends in maintaining the dominant genetic-engineering research pathway instead of alternatives. We have also shown how despite the controversy creative dissenters from India, drawing support from national and international networks have been able to consistently present alternate facts and building a credible research pathway. We present below a surprising alternative framing that could enable India to be a leader in agroecological research through SRI.

India has been arguably the most active sites for contestations, controversies, dialogues, alliances, innovation and experimentation on SRI. More research on extension of SRI principles to wheat, sugarcane, mustard, finger millet, etc., has happened from India in what is now being termed as the System of Crop Intensification.

FIGURE 1
India's Journal Contribution to SRI Publications (2000–2017)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
India	0	0	0	0	2	3	6	6	15	24	24	17	33	49	32	28	26	46
China	1	2	2	17	18	11	13	7	4	8	5	6	5	7	3	1	16	1
World	1	2	4	20	26	21	28	20	26	41	42	59	64	91	89	55	90	79

Source: The author (collated from analysis of SRI Rice data).

This field evidence, is surprisingly, reflected in publications too. Figure 1 shows the distribution of SRI publications in different journals from 2002 to 2017, and the share of Indian and Chinese researchers' contribution to the same.

China dominated SRI research until 2007 and though Indian research on SRI began slowly India has dominated global publications on SRI since 2008. Indians share of world journal output on SRI is in excess of 47 per cent of world total. While not all the articles from Indian journals are of even quality and Indian researchers could do better by using the available information available in the SRI research networks and work towards better coordination and organising their own work, it is important to recognise that India has an unusual opportunity to lead research on agroecological innovations. Instead of being an 'also ran' in the race in genetic engineering research would the Indian research establishment shed its reluctance and reimagine responsibly the innovation of its own researchers by taking leadership and charting a new research direction? Would responsible innovation in the Indian context of agricultural research mean greater openness to ideas from farmers, CSOs and its own dissenting researchers? Can this reimagined RRI happen without a recognition of the politics of knowledge in sustainable transition? Research on SRI is promising, but still a work in progress. There are cases where SRI has not worked as well as usually reported, and farmers have reasons for preferring some principles of SRI more than others (Sen, 2015). SRI, we suggest, is neither a panacea for either the challenges facing farmers across India nor the solution to reforming the Indian agricultural establishment. It is a responsible innovation that can open up pathways for future research and needs more mainstream research funds than has been the case.

The case of SRI helps us explore the various dimensions of RRI in the Global South and in agriculture. Responsible innovation needs to be situated within the

broader frame of knowledge and its politics. Scientific controversies are sites that not only reveal the uncertain nature of science but also provide us an opportunity to socially construct alternatives by looking more closely at innovation at the margins. RRI as a frame is welcome and can be empowering if the anticipation of futures is more proactively engaged in the process of mapping alternative knowledge systems in the Global South. Reflexivity of researchers and innovators could benefit from understanding creative dissent in the South as much reflexivity is often under the radar and is often discovered in multi-stakeholder interactions and dialogues. These researchers on SRI provided newer narratives challenging the mainstream view of rice production and knowledge surrounding it. They presented several lesser known dimensions worthy of research that could translate into alternate research programmes. The SRI case suggests that it is indeed possible to have an alternative narrative to agricultural research where India could be leading the world on agroecology while at the same time empowering its farming communities. This is a dramatic counterpoint to the often-voiced criticisms of an ossified agricultural research system in India where 'nothing of significance has emerged from this system to galvanise farming in recent decades' (Jishnu & Sood, 2015).

Inclusion of civil society organisations and their knowledge might be a key learning on RRI in the Global South. As we have seen, CSOs can create knowledge spaces and dialogues that can empower farmers and dissenting researchers. Networks, both local and transnational, have an important role to play in the governing of innovation. There is a case for reworking the RRI concepts of anticipation, reflexivity, inclusion and governance as my analysis of SRI would indicate. RRI can be an empowering frame in the Global South if there is a stronger programme to present bolder visions of the future, such as India being a leader in agroecology and present insights into constructing newer socio-technical worlds that would be more inclusive of farmers' knowledge and those from civil society.

The SRI case shows that a sustainable transition in agriculture research would require more than simply increased funding and expenditure to continue research along its current trajectory, which is evidently constrained by diminishing returns. It also directs attention to the larger framework and power that influences S&T choices. The RRI project in the Global South needs to be reimagined both in terms of its understanding on knowledge as well as in proactively creating spaces for knowledge dialogues. The messy and complex journey of SRI in India offers some insights in re-imagination project.

DECLARATION OF CONFLICTING INTERESTS

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

The author would like to acknowledge the support of the Fulbright Nehru fellowship at Cornell University in 2013–2014 that enabled some of this research.

NOTES

1. A recent exploratory RRI dialogue in India focused on India's leading scientific agency, the Department of Science and Technology (DST) and suggested some practices that resonate with RRI in Europe. Indian experiences, it was suggested, could contribute to ongoing discussions on RRI. See the policy brief by RIS (September 2018) following a workshop on RRI in April 2017 http://www.ris.org.in/sites/default/files/RIS_%20RRI%20National%20Policy%20Brief%20in%20English.pdf
2. For the presentation by R. A. Mashelkar on this theme visit http://niti.gov.in/writereaddata/files/NITIAyog_Presentation.pdf. The new umbrella organisation, the Atal Innovation Mission, strongly links innovation to start-ups and entrepreneurship. See http://aim.gov.in/overview.php
3. For STIP see http://www.dst.gov.in/sites/default/files/STI%20Policy%202013-English.pdf and for technology Vision 2035 visit http://www.tifac.org.in/images/tifac_images/2035/tv2035/TV%202035%20Doc-Last%20final-release.compressed.pdf
4. Rice and wheat occupied 90.1 per cent of the area in Punjab and contributed 76.9 per cent towards production in 2014–2015, the combined area under other crops, which in 1966–1967 was 54.54 per cent, has decreased drastically to 9.87 per cent in 2014–2015 (Mann, 2017).
5. See www.sririce.org
6. See http://sri.cals.cornell.edu/research/index.html
7. For details on the article on Nature and the response of Dr Satyanarayana see http://www.i-sis.org.uk/TIRGRSRI.php. The site traces the scientific controversy on SRI in some detail.

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'We Do Not Want Fake Energy': The Social Shaping of a Solar Micro-grid in Rural India

AVIRAM SHARMA

During the last two decades, numerous policy actors have advocated multiple models for the diffusion of solar energy-based technologies in India. In recent years, the social development-based energy business model was promoted by some NGOs, civil society groups and academicians for reaching the poor for meeting their energy needs. Using a case study approach, this article explores the social shaping of a solar micro-grid established in rural Bihar through the hybrid model of environmental governance. The article employs the social shaping of technology framework to explain the top-down and bottom-up interpretations of the solar micro-grid in rural India. By focusing on the idea of citizens and consumers, it explains the influence of the wider socio-political context in closing down the debate and stabilising the choices. The article illustrates the implications of the narrow framing of the socio-technical ensemble by the NGO's and civil society groups (top-down perspective) on the diffusion potential of the solar micro-grid. The bottom-up perspective adds more layer to the interpretation of the socio-technical ensemble. An integrated, comprehensive understanding based on both the top-down and bottom-up perspective would help in developing a responsible research and innovation paradigm.

Keywords: Social shaping of technology, SCOT, solar energy, new technologies, rural India

Introduction

India, one of the fastest growing economies in the world over the last two decades, has not been able to provide hundred per cent access to electricity at household level in the rural areas of the country (Dugoua, Liu, & Urpelainen, 2017). Nevertheless, in April 2018, the Prime Minister of India declared that every single village in India has now access to electricity. Interestingly, it does not mean that now every

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Science, Technology & Society 25:2 (2020): 308–324
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820903006

household has access to electricity. According to the Government of India (GoI), if 10 per cent of the households in a village get connected then it can be declared as 'electrified' (Oda & Tsujita, 2011). According to some reports, only 7.3 per cent of the total 18,452 villages in India have 100 per cent household connectivity.[1] Thus, energy poverty is a perennial issue in the rural areas of India (Bhide & Monroy, 2011). Further, there is a great mismatch in energy access in different provinces of India (Kemmler, 2006; Oda & Tsujita, 2011). The more critical challenge is to ensure reliable and affordable access to electricity in a sustained manner. Bihar, one of the eastern states of India having a predominantly rural population (around 88 per cent), has still thousands of villages and millions of families without electricity. According to the Government of India, around 15.75 million households were un-electrified in rural areas and around. 0.306 million un-electrified households in urban areas of Bihar until March 2015. The state government planned to reach to 14 million households in rural areas through different programmes using both grid and off-grid solutions by 2019 (GoI, 2015).

In this background, a unique experiment took place in Bihar in 2014 for addressing the energy poverty in rural areas. A solar-based micro-grid was established in a village named Dharnai in Jehanabad District (Greenpeace, 2014a). Jehanabad is notoriously known in Bihar for several incidences of caste-related killings or caste-wars during the 1990s (Kunnath, 2008). The Greenpeace established possibly the first solar village in the country. Unlike a pure state-led developmental intervention or a pure market-led or community-led project, this project was a collaboration between an international environmental NGO (Greenpeace India), civil society organisations (BASIX and the Centre for Environment and Energy Development-CEED)[2] and the local rural communities (villagers). This multi-partner model is conceptualised in the environmental and political science literature as hybrid environmental governance (Agrawal & Lemos, 2007; Rhodes, 1996). Hybrid environmental governance implies the joint action of different actors, such as state agencies, communities, businesses, non-governmental organisations and civil society organisations.

Contrary to the dominant model in the country in which electricity connectivity is provided in rural areas through centralised conventional grids (Kemmler, 2006), this was a decentralised rural electrification model, completely based on renewables. In this hybrid model, the role of the state was weakly envisioned. Instead of the state, the market-based actors were supposed to take the lead role in rural development. The village community was acknowledged as an active partner rather than passive receivers of state interventions. The villagers were trained by the Greenpeace India, BASIX and CEED for maintaining and regulating the solar micro-grid use. This hybrid model was presented as an exemplary case for connecting villages in the rural areas of Bihar, where main grid connectivity was not possible due to geographic and other reasons.

Greenpeace India considers the decentralised rural electrification model as an ideal model for knowledge creation, awareness generation, technology demonstration and policy development in rural India. The decentralised renewable-based rural electrification models have been advocated by many other scholars (Chaurey &

Kandpal, 2010; Kabir, Kumar, Kumar, Adelodun, & Kim, 2018; Kumar, Kumar, Kaushik, Sharma, & Mishra, 2010; Oda & Tsujita, 2011; Raman et al., 2012). In India, both central and different state governments are vehemently advocating for solar energy. Under the National Solar Mission (2010), the central government wanted to achieve 'the ambitious target of deploying 20,000 MW of grid-connected solar power by 2022', which has been revised in 2015 to achieve the total solar power capacity target of 100,000 MW (40 GW rooftop and 60 GW grid connected).[3] The hybrid model of off-grid installation of solar energy technologies in rural Bihar is part of these broader schemes of things. Moreover, solar energy is being pushed by experts and promoters as a potential solution for confronting phenomenal environmental challenges such as climate change and meeting the future energy demand (Creutzig et al., 2017; Jawaharlal Nehru National Solar Mission, 2010; Kabir et al., 2018; Sims, 2004).

In this background, the article deals with the top-down and bottom-up approaches to understand this new technological intervention in rural Bihar and the diffusion dynamics of solar-based micro-grid at the village level. The article draws conceptual framework from the social shaping of technology (SST) (Bijker, Hughes, & Pinch, 1987; Williams & Edge, 2006) and the Public Understanding of Science (PUS) (Michael, 1998, 2009) literature. The article explores three major research questions. First, how do the different social groups understand, envision and interpret this new technology? Second, how are different values associated with solar energy and other alternatives negotiated by the local community and outside actors involved in this project? And third, how can the framing of the social groups under the lens of 'public in particular' and consumer/citizen (Michael, 2009) help us in understanding the technological choices made by the local villagers?

The article employs two sets of methods for data collection. To collect the bottom-up understanding, the article primarily draws from the fieldwork carried out in Dharnai between 2015 and 2017. By bottom-up perspective, we imply the opinion of villagers who were the beneficiaries of this project. The author has conducted qualitative interviews among the following groups: users of solar micro-grid including, farmers, agricultural workers, solar micro-grid operators, local village committee members and several non-users of the technology in the four neighbourhoods (Dharnai, Dharnai mahadalit tola, Bishunpur and Jhitkoria) of the village. Overall, fifteen individual interviews and eight group interviews were conducted. The interviews ranged between 15 minutes and 50 minutes. All the interviews were recorded and transcribed. To collect the top-down understanding of the relevant actors, we primarily relied on government reports, news reports, policy documents, reports prepared by NGOs (Greenpeace) and civil society groups (CEED), and the official website developed by the promoters named Dharnai Live. The top-down understanding implies the opinion of the domain experts, and more specifically the promoters of this project. The data collected through these methods were analysed with the help of the conceptual framework discussed below.

The article is divided into seven sections. The next section presents the conceptual framework. The third section provides background information about the

overall electricity scenario in Bihar and specifics of the new hybrid model introduced by Greenpeace India and their associates in Dharnai. The fourth, fifth and sixth sections discuss the case, and finally, the final section offers the concluding remarks.

The Social Shaping of a Solar Micro-grid: Understanding Technological Choices

Under the broad ambit of SST, social construction of technology (SCOT) is one of the widely used frameworks to analyse the social shaping of technological artefacts (Bijker, 2010; Williams & Edge, 2006). Innumerable studies have employed this framework to explore diverse issues, ranging from study of facts and artefacts (bicycles) (Pinch & Bijker, 1984), mountain bikes (Rosen, 1993), automobile (Kline & Pinch, 1996), environmental indicators (Elle, Dammann, Lentsch, & Hansen, 2010), clinical trials (Bijker, Sauerwein, & Bijker, 2016), recumbent bicycles (Ahmed, Qureshi, & Khan, 2015), contraceptive technology (Watkins, 2011), nano water filter (Saidi & Zeiss, 2016) and many more.

Continuing this line of thought, in this article, we will study the social shaping of a solar micro-grid in rural Bihar. In empirical terms, the literature on the social shaping of technologies in rural areas and especially in developing countries is mostly missing. Further, this case provides an opportunity to intervene in theoretical terms. The complexity among different social groups (in rural population along the line of caste, economic disparity, rurality, embeddedness in political systems) in our case will help us to further extend the debate on the idea of relevant social groups. The hybrid model promoted by Greenpeace and other civil society groups emphasises that this model is led by community actors and involves wider participation of local community in governance (Greenpeace, 2014b). However, they view the local community as 'public in general', where the public is conceptualised as 'uniform and total', whereas the internal differentiation among the public is downplayed. In 'public-in-particular' framework (Michael, 1998), the public has an identifiable stake in particular technological issue/controversy, and the internal differentiation among the public is brought in the discussion. To bring out these aspects, we will draw from the PUS literature which delineates the tension among the idea of the public as consumers and citizens (Michael, 1998, 2009). Similarly, in this article, we emphasise the role of the *wider social context* in shaping technological choices. The SCOT literature often does not pay enough attention to the wider social context in shaping the closure (Klein & Klineman, 2002; Rosen, 1993) and is criticised for ignoring structural embeddedness (Sovacool & Hess, 2017). We believe the idea of 'public in particular' and the consumer/citizens distinction complements the SCOT perspective, and this fusion is helpful in further strengthening the conceptual framework of SCOT. It helps in explaining the wider socio-cultural and political milieu in shaping the closure. The consumer/citizen distinction will help us understand how the rural users of the solar micro-grid view themselves, as common consumers (as envisioned by Greenpeace and their partners) or do they emphasise the idea of citizenship and entitlements. A different

conceptualisation of the public will have a bearing on understanding the impact of the *wider social milieu* in shaping individual/public choices.

In this study, rather than taking photovoltaic (PV) cells as a single technological artefact or categorising solar micro-grid as a technological system, drawing from Bijker (2010), we will employ the idea of the socio-technical ensemble. We see technological and social issues as complexly intertwined with each other, and thus they present a 'seamless web', which cannot be analysed using other categories. Employing the idea of relevant social groups and interpretative flexibility we will analyse the top-down and bottom-up narratives on solar micro-grid. We believe, the social setting of rural Bihar, exhibiting extreme economic and social disparity among masses (Sharma & Rodgers, 2015) will help us understand the multiple ways in which the solar micro-grid was understood by the different user and non-user groups. Finally, we will explore the question of closure and stabilisation. How were the choices being made? How the negotiations about the meaning and potential benefits of the solar micro-grid among different local social groups got closed? In this context, the idea of technological framing (Bijker, 2010) would be used to analyse the responses. The idea of changing technological framing and dynamic positions of relevant social groups is crucial in this case. Unlike many existing studies (Ahmed, Qureshi, & Khan, 2015; Kline & Pinch, 1996; Pinch & Bijker, 1984; Rosen, 1993; Watkins, 2011), which used the SCOT framework for analysing the social construction of technologies in historical contexts, we analyse a contemporary case which is still unfolding.

A Hybrid Model Based on Decentralised Renewable Energy for Tackling Energy Poverty in Rural India: The Case of Dharnai

According to some studies, around 450 million Indians are living without electricity (Kemmler, 2006). Bihar is one of the most energy-deficient states of India (Oda & Tsujita, 2011). The installed power generation in Bihar is way below the other industrialised states, such as Maharashtra and Tamil Nadu and so is the per capita consumption against the national average. To overcome the energy deficiency, the state government has pledged to increase the investments in renewable sources of energy to increase the installed power generation capacity. Non-conventional sources such as solar PV technology is promoted for increasing energy access in rural areas of the state, especially after 2011. Several government policies and schemes are devised for promoting grid connectivity and off-grid models.[4]

As part of such interventions, the decentralised micro-grid (100 kW) was installed in Dharnai at the cost of around $497,700 by Greenpeace and partners (BASIX and CEED were the co-implements).[5] The tariffs were decided by the village level committee (VLC) in consultation with the BASIX and the local residents of Dharnai. According to Greenpeace, the micro-grid was capable of supplying power to 3,000 people (Greenpeace, 2014b). Greenpeace advocated the mini and micro-grids as a more effective, reliable and sustainable alternative for rural electrification (Greenpeace, 2014a, 2014b; Gurtoo & Lahiri, 2012; Khator

& Kumar, 2014). The experts working with Greenpeace envisioned Decentralised Renewable Energy System (DRES) or distributed micro-grids as the solution for addressing energy poverty in rural areas (CEED, 2014; Greenpeace, 2014a, 2014b; Gurtoo & Lahiri, 2012). The solar grid in Dharnai was supposed to provide electricity supply for all kind of purposes, that is, residential use, commercial use and agricultural use (Greenpeace, 2014a).

In this hybrid model, the finance was supposed to be invested by private players, civil society organisations were supposed to train the local community, and finally, the local community was supposed to drive and manage these projects (Greenpeace, 2014b). It was projected as a social development-based energy business model, which was self-sustainable and required little support from outside actors (state or non-state actors) once the project is established. The next section analyses how the experimental social development-based energy business model for bringing rural transformation and addressing environmental challenges unfolded over the years after its establishment in Dharnai.

Interpreting the Solar Micro-grid: The Top-down and Bottom-up Narratives of Relevant Social Groups

The top-down and bottom-up perspectives to analyse relevant social groups explicates the major stakeholders involved in this project. Greenpeace and their partners considered the local community as 'uniform and total' and downplayed their internal differentiation. In other words, for Greenpeace and partners, the local community was 'public in general' (Michael, 2009). Greenpeace and their associates formed a major social group in our case. They viewed the solar micro power grid as an effective, reliable and sustainable way to provide access to electricity (CEED, 2014; Greenpeace, 2014a, 2014b). From the bottom-up perspective, we identified a couple of non-user groups[6] (Elle et al., 2010) as a relevant social group which shaped the diffusion of solar micro-grid. After the installation of the solar micro-grid in Dharnai, the promoters of the project (Greenpeace, BASIX and CEED) invited the former Chief Minister (CM) of Bihar Nitish Kumar to formally inaugurate the project in August 2014. By this time, the project had received huge publicity in the national and regional media (Khator & Kumar, 2014). The solar micro-grid has started providing electricity, and all the four major neighbourhoods in Dharnai were getting electricity supplied through this micro-grid (Greenpeace, 2014a). When the former Chief Minister visited the village to inaugurate the project, a small group from the village, greeted him with provocative slogans and placard. They demanded, 'We do not want fake energy, give us the real one'. According to this small group of protestors, solar energy provided through micro-grid was fake energy and conventional grid connectivity was the real source of energy.

This non-user group advocated for conventional grid connectivity instead of renewables-based solar micro-grid. The protest was led by the educated adults

> from the farming families of the upper caste. A couple of them (the organisers and the leaders of the protest) were already working towards getting their village connected with the central grid before this Greenpeace initiative unfolded for their village. They have visited the State Electricity Board Office several times and petitioned for grid connection in Dharnai. Thrice they have attended the Janta Darbar of the CM to submit their application for getting grid connectivity.[7] These youths, supported by some other non-users (agricultural workers from marginalised communities) of solar micro-grid in Dharnai, saw the visit of the former CM as an opportunity to express their long-pending demand. This social group interpreted solar micro-grid as an inefficient system, which was incapable of addressing their energy poverty. The existing users and early adopters of the solar micro-grid in the village pursued this group of non-users to not to show such placard. The early adopters and users of the solar micro-grid formed the third major social group. The non-users persisted with their demand in front of the CM. The former CM accepted their demand, but made the remark that '[s]olar energy is the real energy, which will stay forever and the conventional one is fake, which will deplete over the years.'
>
> —(Fieldwork) As narrated by the villagers

Two different interpretations of the same solar-based micro-grid presented and promulgated by different social groups (non-users from the village and users and the promoters of the micro-grid) in Dharnai contradicted each other (Pinch & Bijker, 1984; Saidi & Zeiss, 2016). The non-user group saw the solar energy as the stop-gap arrangement and the conventional energy supply through the centralised grid as the permanent technological solution. The former CM and the non-state promoters of the project, which represents the expert-led top-down vision of the technology emphasised on the finiteness of the coal reserves and the infinite nature of solar energy. The top-down view is endorsed by several scholars working on renewable sources of energy (Creutzig et al., 2017; Kabir et al., 2018; Oda & Tsujita, 2011; Raman et al., 2012). The former CM announced that the demand of the non-users of Dharnai would be met by the state. After this event, within a month the village was re-connected with the conventional grid.

The integration of Dharnai with the centralised grid substantially depleted the chances for wider adoption of the solar micro-grid connections in the village. CEED envisioned that 'The 100 Kw solar micro-grid at Dharnai is going to power about 500 households, 50 commercial shops and other social infrastructure like schools, hospitals and *panchayat bhawan* etc.'[8] However, this political rupture and the clash of ideas on the nature of technologies which can fulfil the demands of the villagers has led to a drastic reduction in the number of connections among the residential users (see Table 1).

The social groups are also not static in their composition. Their make-up can also change with altering interpretations and varying technological framing (Bijker, 2010). When Dharnai was un-electrified, many families from the weaker socio-economic backgrounds also adopted solar micro-grid for re-electrification. Dharnai has a sizable population of Schedule Castes (SC) population, also termed

Table 1
Number of Solar Micro-grid Connections in Dharnai

Name of the Neighbourhoods	*Solar Connections (2014)*	*Solar Connections (2015)*	*Solar Connections (2016)*	*Overall Drop*
Dharnai	60	28	35	25
Mahadalit Tola	45	03	0	45
Bishunpur	80	45	15	65
Jhitkoria	70	70	70	0
Total	255	146	120	135

Source: The author.

as mahadalit by the state. The village has around 225 mahadalit families, out of which, initially around 45 families signed for solar energy. This was made possible due to the efforts of Greenpeace and BASIX campaigners. One of the female respondents from the mahadalit tola stated that

> We left solar connection after using it for one year. How can poor people like us pay such amounts of money? They used to give electricity only for two hours. During rain, they do not use to give electric supply and so does during the fog in the winter.

Every user of the solar micro-grid from this neighbourhood abandoned the solar connection when the main grid connectivity was provided to the village. In other words, when other options emerged for them, they abandoned the existing solution. Whereas, in another neighbourhood, *Jhitkoria*, where the villagers have not received the main grid connection, the early users continued to use solar power. Whereas, in the mahadalit tola, the early users initially acted as a passive receiver, but with the change in electricity provisioning scenario in the village they asserted their interpretation, which was counter to the position fostered by the promoters.

During the initial year, the promoters of the project were unable to provide individual electric meter in the households for residential use. Instead of that, two packages were offered. In package one, the consumer had to pay ₹75, and they were allowed to use one bulb and one plug point for charging mobile. Additionally, the users had to pay a security deposit of ₹500 for availing this service. In package two, the consumers had to pay ₹140 and they were allowed to use three bulbs and one plug point. For this package, users were supposed to pay a security deposit of ₹1,000.

In the initial three months after the inauguration of the project, the users faced no problem, as the energy requirement among the users was limited. However, within six months, many of the users have started overusing the power supply and started using other heavy electrical appliances (such as TV, electric heater for preparing food). The micro-grid was not able to continuously generate enough electricity for meeting the increased demand. The unmet expectations and the desire of using more electricity created discontent among the villagers. To overcome this, BASIX

and CEED with the help of VLCs conducted a campaign about the do's and don'ts in terms of using electric appliances. However, the VLC failed to implement those norms for judicious use of the solar connection. Several consumers abandoned their solar connection after this episode in Dharnai. The promoters of the project interpreted the solar micro-grid as a solution to the existing energy poverty of the villagers (CEED, 2014; Greenpeace, 2014b). However, the users were not only interested in solving their immediate concerns but looking for solutions, which were able to meet their increasing energy demand. The idea of hybrid governance (Agrawal & Lemos, 2007), which emphasises joint action by different groups, failed to get operationalised in this context. The local community found it difficult to regulate and manage the project on its own, as envisioned by Greenpeace and associates (Greenpeace, 2014b).

The multiple relevant social groups described above have differently interpreted the same socio-technical ensemble. The external service providers believed that solar energy is the future and decentralised rural electrification is the new model, which would be adopted widely (CEED, 2014; Greenpeace, 2014a; Gurtoo & Lahiri, 2012). Greenpeace and their co-partners also interpreted the solar micro-grid as a solution for addressing the global environmental problems, and a system capable of meeting the specific needs of diverse social groups, especially the poor sections of rural India. In their own words, 'Decentralised Renewable Energy System (DRES) or distributed micro-grids can be designed to meet the specific power needs of different populations on a variety of different scales, and therefore, are an inclusive solution that can meet the needs of diverse economic segments.'[9] As described above, the weaker sections of Dharnai were the first to reject this interpretation of solar micro-grid.

Within Dharnai, there were multiple social groups (user and non-users) having a diverse socio-economic and educational background, and they interpreted this socio-technical ensemble in their own ways. Many in the upper-caste farming families were existing users of low power (40 W to 80 W) rooftop solar plates. They saw the supply from the micro-grid as an additional source of power, which supplemented their daily needs. In their world view, solar power was an alternative to address their energy poverty and later on it augmented their overall energy requirement. The adoption of private solar rooftop panels was minimal among the poor upper-caste farming families. They continued with kerosene-powered lantern and later switched to conventional grid. In the second phase, in January 2016, the promoters of the project installed electric meters in every household. The per unit (kW hour) price of solar energy was fixed at around ₹9, whereas the per unit price of electricity supplied through the main grid in rural Bihar was around ₹3. Definitely, there was no financial rationale for using solar energy. Many of the farmers perceived that solar energy is not going to fulfil their energy demands and is a wasteful option in terms of financial investment. One of the farmers stated that '[t]he original energy is provided through the main grid connection, as with that we can irrigate our field and get proper supply. The capacity of solar energy

is too low, almost zero in comparison to the main grid.' The top-down narratives on solar micro-grid, which are led by civil society groups and experts, completely differed from the bottom-up narratives given by the villagers.

Apart from the residential users, the project also envisioned to provide solar-based renewable energy to farmers (Greenpeace, 2014a). Unfortunately, none of the farmers were interested in using the solar energy for irrigation purpose. Agriculture is a major sector in rural Bihar (Sharma & Rodgers, 2015), which requires huge energy supply to sustain different agrarian activities. There were more than 100 diesel-based pumps for irrigation in the village. One of the farmers while comparing solar energy with other sources stated that

> how can we pay exorbitant prices of solar energy? We do not earn that much from farming. We want an electric connection even for agricultural use. The current electric transformer cannot provide enough electricity to meet our farming needs, that is why most of the farmers are dependent on diesel pumps for irrigating fields; solar energy is unable to meet our agricultural energy demands.

This hints at an interesting relation and expectation of farmers from the state. The farmers are expecting increased state support for meeting their energy requirement, rather than the weak role envisioned for the state in the hybrid model for meeting energy requirements. The farmers wish for higher investment from the state for developing rural infrastructure in the agrarian sector.

Closure and Stabilisation of Choices: Rejection/Acceptance of the Solar Micro-grid

From the top-down perspective, the experts envisaged that the solar micro-grid would be accepted by the local community as a solution for their energy poverty. The environmental benign nature of the technology was believed to further stabilise their choices (CEED, 2014; Greenpeace, 2014b). Interestingly, the closure and stabilisation of choices (Pinch & Bijker, 1984) in this case did not happen because of environmental considerations. Most of the respondents in Dharnai stated that they were unaware of the main source of energy through which the electricity is produced in the conventional grids. The environmental dimensions and the finitude of resources of the conventional sources failed to influence their choice. For the experts, it is one of the major factors for advocating renewables (Kabir et al., 2018). Only very few selected individuals from the village shared that understanding; mostly, the educated farmers in Dharnai and few other educated individuals from other backward communities in Jhitkoria. Even among them, acceptance of this technology was not based on environmental considerations, but primarily due to other reasons. For the farmers, it was a matter of prestige, as they were the leaders and early adopters. This project has given them visibility.[10] For other users, it was because of the lack of alternative (one of the neighbourhoods was not connected with the main grid). The closure happened by redefining the problem (Pinch &

Bijker, 1984). The user groups re-defined the problem. The solar grid was not a solution to their energy woes but an alternative for some to augment their energy supply and for others a stop gap measure. Whereas, the individuals from the SC population were not at all interested in the environmental dimensions or any other aspect of the technology (even as an alternative). Even though their electricity requirement was minimal, but they declined to engage with this new socio-technical ensemble. Either they continued with the kerosene oil to lighten up their houses or moved to the main grid. The majority of the population from the SC community rejected the solar micro-grid, and for them, the closure had been reached after the availability of main grid connectivity.

For almost all the social groups in the village, the end matters most (energy sources capable of fulfilling their daily requirements), not the origin or source of the energy. From the top-down perspective, the origin of the energy source was crucial. It was argued that environmentally benign renewables will be widely adopted due to environmental considerations (Kabir et al., 2018; Khator & Kumar, 2014; Sims, 2004). The aspirations of the villagers were discounted by the service providers. It was assumed that they will continue with the subsistence mode. The unmet expectations from the solar energy in terms of receiving continuous energy supply for residential purpose helped in stabilising their technological choices in favour of the main grid connection.

The hybrid model (Agrawal & Lemos, 2007) was supposed to encourage the wider adoption of solar micro-grid (Greenpeace, 2014b). In all the four neighbourhoods, during the initial stages of the project the local VLCs were created with the help of BASIX and CEED, but they became completely dysfunctional in the mahadalit tola and Bishunpur within some time. In Dharnai and Jhitkoria, members of the committee narrated the difficulties in enforcing rules or norms in their neighbourhood for restricting the use of different electrical appliances by the users. When they failed to implement the rules at the household level, they devised a way to curb energy overuse by changing the timings for supplying electricity. Instead of giving electricity all through the day, they restricted the supply only in the evening and the night. This was to discourage users from using solar energy for heavy electrical appliances during the daytime. However, the unavailability of the electricity, all through the day, encouraged the discontented users and non-users to ascertain that solar micro-grid is not the solution for their energy woes.

The political rupture and connection with the main grid due to the insistence of non-users was the second major factor which led to the closure and stabilisation of choices among different user groups within the village. The closure and stabilisation, in this case, were dependent on the perception of users about themselves as consumers or citizens (refer to the next section) and their expectations from the state, apart from their interpretation of the solar micro-grid. Rather than considering them as 'public in general', the public should have been viewed as 'public in particular' (Michael, 2009). The 'public in particular' implies that the public who is directly involved in this project. The concerned public has a different say over various

matters, in comparison with 'public in general', who are not directly involved in a project. Within this 'public in particular', the early adopters were big farmers, who were using solar rooftop panel before the micro-grid was introduced. They produced their energy and consumed it in the absence of electric supply provided by the state. This new source added to their overall energy supply. The families who were living without PV cells first adopted it in the absence of any better alternative and then rejected it once the electric connection was established through the main grid. They agreed to become the energy consumers in this new arrangement under the hybrid model. However, once the state returned back as the main service provider, they abandoned their role as the consumer of solar energy produced by the hybrid model. They returned back to the conventional service provider, that is, to the State. Among this particular public, the concern for green energy was minimal. Rather than looking for the nature of the technology and its environmental benefits, the 'public in particular' was interested in getting proper uninterrupted supply of electricity from the conventional grid. As the supply from the micro-grid was only able to meet their basic demand and not enough for meeting their increasing demands, it was rejected by them.

The agricultural labourers were also enrolled as the consumers in this hybrid model, but it seems they were not ready to reconcile with that identity thrust upon them by Greenpeace and their associates. Some of them initially adopted the new technology promoted by the NGO's and the fellow villagers but once the village was re-connected with the main grid, they immediately switched the side. The agricultural labourers abandoned their role as consumers and preferred to become the citizens having entitlements. The promoters of the project viewed the whole local community only as consumers. The state provides subsidised electricity to this social group given their low socio-economic status. Community engagement in the hybrid model is based on the neo-liberal economic assumptions, which constitutes public as consumers (Beumer, 2017). It is important to note that the majority of the mahadalit community not even got enrolled for the solar energy provided through the micro-grid from the beginning. Paying the 'affordable price' set by the VLC and the project partners for solar electricity was not affordable to them. A number of them asserted that they are entitled to get free electricity from the government. They rejected to act as a consumer of solar energy in the hybrid model. During this period (2014–2015), many of the nearby villages were connected to the centralised grid by the efforts of the state machinery. It further eroded the worth of solar energy provided through the hybrid model.

The Wider Context: Citizens vs Consumers

How the wider socio-cultural and political situation shapes the values of different social groups is one of the less explored dimensions of SCOT (Klein & Klineman, 2002; Pinch & Bijker, 1984). In this article, I have augmented this dimension by bringing insights from PUS literature (Michael, 1998). Greenpeace and associates

viewed the local community as a 'homogenous community of consumers having a limited requirement', whereas contrary to this view, different social groups within the village mostly failed to envision themselves as active decision-makers as consumers. Greenpeace developed this project as a market-based solution. In their words, in this model, scarce government resources will not be utilised to provide electricity to the rural population. Instead of that, small investors will invest in these low-cost projects (Greenpeace, 2014b).

The hybrid model was expected to help in capacity building in the villages and was meant for creating rural jobs. Within a year, it became evident that the staffs working for the project were not even able to collect enough rent from the users. The project was supposed to be self-sustainable and led by the community after the initial support of outside actors (private business, NGO's, civil society groups) in setting the project (Greenpeace, 2014a). The local community never took complete control of the system. The village community is not a homogenous group, and it is marred along different socio-economic and cultural parameters. Ignoring the internal differentiation and the changing conceptions of community identity would be a serious mistake (Kumar, 2005).

Second, the state is still having towering influence in the life of common public in rural areas of India. Especially, the lower socio-economic groups rely on state support. In Bihar, the state has the policy to provide free electricity connection (100 per cent capital subsidy) to families below poverty line (BPL) and subsidised tariff for the rural population.[11] All the mahadalit families in Dharnai were under BPL, and they preferred to abandon the use of solar power once the village was connected with the conventional grid and shifted to the main grid. A female respondent while emphasising on her mahadalit identity asserted her entitlement from the state along with the helplessness while describing the main grid connectivity in her house. She said,

> If we were able to pay and would have paid then why would we had been categorised as *mahadalit?* We are using the main grid connection without paying; if we will be coerced to pay then we will ask the state to take back the connection, we cannot pay like the farmers.

The women respondents from SC communities stated that

> the kerosene lantern cannot be abandoned, that is going to stay. From our birth, we are seeing it, that remained constant, electricity given by the state is just a fashion. Even now, often when there is no electricity, we rely only on lantern and lamps.

The narrative explains the deep-seated inequalities among the different social groups within the village, and which shapes their values, norms and understanding. It would be erroneous to treat different social groups within the village as a 'homogenous community' or consumers of services, which has been traditionally provided by the

state; as it was done by the Greenpeace and their partners while implementing the project (Greenpeace, 2014b). Within a year, large sections from this social group have entirely forgotten this new technological experiment that happened in their village. The environmentally superior renewable technology was summarily rejected by the most socially and economically disadvantageous communities of the village.

Conclusion

In pursuit of the hybrid model of environmental governance (Agrawal & Lemos, 2007), Greenpeace and their associates co-implemented the solar micro-grid project in Dharnai as an alternate model for rural electrification in rural Bihar. The article employing the conceptual framework of SCOT and fusing it with PUS literature explains how various social groups (promoters/experts/farmers of different categories/agricultural workers/other rural communities/non-users) have interpreted the same socio-technical ensemble differently. In the top-down narratives of the experts and the promoters of the project (Greenpeace, BASIX and CEED), the solar micro-grid was envisioned as an environmentally superior technology, affordable to the local community and democratically controlled and governed by the community actors. The bottom-up narratives given by the various relevant local social groups were focused on the functional limitations of the socio-technical ensemble, the idea of 'real' and 'fake' energy, the distrust on the solar micro-grid for meeting their energy requirements.

From the bottom-up perspective, the social groups did not view the solar micro-grid as a solution to their energy woes. The solar grid was an alternative for some groups to augment their energy supply, whereas for others it was merely a stop-gap measure. The local groups failed to acknowledge the environmental benignness of the technology, which was a major reason for the promotion of this technology by the experts (CEED, 2014; Greenpeace, 2014a; Kabir et al., 2018). The closure happened along two lines, by redefining the problem and because of the political rupture. For one user group, it was a matter of prestige and for the other, the absence of any viable alternative was the reason for acceptance of the solar micro-grid connection at the household level. Similarly, the political rupture, which happened with the interference of non-user groups sealed the fate of the project. The non-users succeeded in getting the main-grid connectivity by the interference of the former CM of the state during the inauguration of the project. The failure of the solar micro-grid to meet the increased demand of the users and the failure of the village electrification committees in enforcing norms for judicious use of solar power stabilised the choices of the users. The article also explained the influence of the wider social context in shaping the solar micro-grid in Dharnai. At a broader level, most of the social groups within the village failed to envision themselves as consumers. More importantly, the weaker sections asserted the idea of entitlements, which they receive from the state. They expected the state to provide them energy and rejected the idea of becoming the consumer of a solar energy-based hybrid model.

The non-state actors involved in promoting this hybrid model viewed the village community as a homogenous group capable of self-organising themselves and looked at the users from the lens of the consumer. The article argues that it is erroneous to consider the rural community as a homogenous group, the internal differentiation and the changing conceptions of community identity should be considered while planning such interventions. The formulations of the public as citizens or consumers (Michael, 1998) will have an enormous influence on the shaping of new technologies. The article adds to the STS literature, which explains how the non-users influence the shaping of different socio-technical ensemble. In the hybrid model, the role of the state was made subdued and the market-based rationalities were promoted for the adoption of solar power-based technologies, but public (non-users in this case) intervention has brought the state back. The wider socio-political contexts, thus, pose a great challenge for the wider adoption of this hybrid model for delivering quality energy service to the local communities in resource-constrained settings of rural India. Ignoring the bottom-up perspectives and the wider social milieu while promoting new technological interventions would fail to provide desired results. The article argues that an integrated, comprehensive understanding based on both the top-down and bottom-up perspectives would help in developing a responsible research and innovation paradigm (Pandey, Valkenburg, Mamidipudi, & Bijker, 2020).

DECLARATION OF CONFLICTING INTERESTS

The author declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

FUNDING

The author received no financial support for the research, authorship and/or publication of this article.

NOTES

1. For more information, please refer to https://www.forbes.com/sites/suparnadutt/2018/05/07/modi-announces-100-village-electrification-but-31-million-homes-are-still-in-the-dark/#434c4b3563ba
2. BASIX is a livelihood promotion institution established in 1996, working in eighteen states of India, primarily in the rural areas. For more information, refer to http://www.basixindia.com/ accessed
   According to CEED, it is a 'solution-driven organisation that work towards creating inspiring solutions to maintain healthy, clean and sustainable environment'. For details, please refer to http://ceedindia.org/about/accessed
3. See http://pib.nic.in/newsite/PrintRelease.aspx?relid<hig>=</hig>122566
4. See http://www.breda.bih.nic.in/Solor.aspx#
5. See https://www.greenpeace.org/archive-international/en/press/releases/2014/Greenpeace-supports-solar-power-energy-independence-for-village-in-India/
6. The non-users in our case represent those villagers who were not using the solar micro-grid in Dharnai. It includes people from upper-caste farming families and also families from lower-caste labourers.

7. Janta Darbar is a regular event organised at the residence of the CM, since Nitish Kumar became CM of Bihar in 2004, where he directly interacts with common people and hear their plea regarding different issues in the state.
8. See http://ceedindia.org/ex-cm-mr-nitish-kumar-visits-the-solar-village-*Dharnai*/
9. See http://www.*Dharnai*live.in/about
10. It suggests how the identity of the user groups get reconstituted in the process of adoption (refer to Kline & Pinch, 1996).
11. See https://indianexpress.com/article/india/bihar-to-pay-power-bill-subsidy-to-consumers-nitish-kumar-4593989/

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Responsibility, Representation and Participation: Bureaucratic Steering of Biofuel Research

MAHENDRA SHAHARE and NAVEEN THAYYIL

This article seeks to trace the implicit notion of responsibility in the bureaucratic steering of biofuel research in India—as a useful entry point to think further on framework of Responsible Research and Innovation (RRI) in India. It concentrates on a specific aspect within the RRI framework in particular—public engagement and concerns for greater participation. By engaging with R&D in biofuel technologies in India, the techno-bureaucratic steering of its trajectories and the emphasis on public engagement within RRI frames, this article seeks to bring focus on how S&T governance in India could in principle be made more responsive to societal needs by motivating positive developments in line with public needs.

Keywords: RRI, biofuel research, synthetic biology, public participation, India

Introduction

Synthetic and Systems biology has come to be recognised by policymakers in this decade as the key approach in the development of novel technologies for biofuel production in India. S&T research on biofuel production in India, including in this turn to synthetic and systems biology, is directed and steered through bureaucratic action, as elaborated later in this article. This article seeks to understand the notions of responsibility that underpin this techno-bureaucratic direction for fostering scientific research to supplement fossil fuels with biofuels, as a useful entry point to think further on the framework of Responsible Research and Innovation (RRI)

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Science, Technology & Society 25:2 (2020): 325–340
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820903003

in India. It concentrates on public engagement and concerns for greater participation in particular, which is generally recognised by now as central to the idea of responsibility in future-oriented approaches to S&T governance (Konrad, Van Lente, Groves, & Selin, 2017; Owen, 2014).

There is a fair amount of recognition that RRI as a framework is not explicitly, or 'directly traceable', within the formal Indian S&T policy architecture (Srinivas, Kumar, & Pandey, 2018), even as policymakers are seen to have used the concept of 'responsibility' in ways 'to further national development goals and socio-economic development' (Srinivas et al., 2018, p. 73). What is the underlying notion of responsibility that can be traced as implicit in the bureaucratic steering of biofuel research in India? Literature within science and technology studies (STS) has focused on how the domains of science and politics are not unambiguously demarcated, and where the material and technological world are seen as shaped with often implicit and undefended visions of order and progress (Irwin, 2008). The lack of explicit substantiation of the notion of responsibility in the bureaucratic steering of scientific research on biofuels in India and the implicit concept of political representation that underpins such exercise of responsibility, together call for the attention on public engagement in this article. What visions of progress are implicitly assumed to be 'responsible' in the bureaucratic steering raises questions about public engagement and participation in the direction of scientific research.

As an important contemporary theme in the governance of science and technology, such attention through the RRI framework, in turn, also provides an appropriate vantage point to direct the attention of STS on the innovation systems geared towards biofuel production in India, beyond the by now well-rehearsed moves in technology governance discourses, namely technology assessment, risk assessment, uncertainties and identifying unintended consequences. By engaging with R&D in biofuel technologies in India, the techno-bureaucratic management of its trajectories and the emphasis on public engagement within RRI frames, this article also seeks to bring focus on how S&T governance in India can be made more responsive to societal needs by motivating positive developments in line with public needs. 'Moves toward RRI' has been understood as 'a further development of two-way public engagement with science', allied to 'blossoming of dialogic activities on issues involving science' (Stilgoe & Guston, 2017; Stilgoe, Lock, & Wilsdon, 2014). Resisting the reversion on the emphasis on public engagement as 'stubbornly motivated' by deficit models that sees the practice of public engagement as a legitimating and trust-building strategy (Chilvers & Kearnes, 2015; Stilgoe & Guston, 2017; Wynne, 2006), this article also seeks to emphasise the current limitations in public engagement within anticipatory governance of S&T in India.

Policy for S&T Research in Biofuels in India: A Historical View

S&T research for development of the three generations of biofuels in India have been greatly directed by bureaucratic steering, where the normative mooring of such steering can be located within the discourses of 'national interest' of fuel

self-sufficiency and import substitution, and 'wise use of agricultural resources' hyphenated within agricultural waste, which will be elaborated later in this section. What notions of responsibility can be located in the justifications for this direction, and whether room for any public engagement and deliberation that seeks to guide this exercise of bureaucratic steering exists within such implicit notion of 'responsibility' is explored here.

Since the invention of internal combustion engines, liquid biofuels such as alcohol/ethanol and vegetable oils have been used as automotive fuels before the price advantage caused a shift towards petroleum products in the early twentieth century (Kovarik, 2013). The Indian Power Alcohol Act of 1948 sought to provide a legal framework for the development of the power alcohol industry in independent India, and envisaged sale of petrol with an admixture of power alcohol wherever feasible.[1] While the law was not enforced, energy security in terms of achieving national self-reliance through finding an alternative to crude-oil import has remained a persistent narrative that has shaped the science and policy on biofuels in India, as elaborated later in this section.

Historically, R&D of biofuel technologies in India has been embedded within the discourse of agriculture, waste and energy (Maheshwari, 2008). Renewable biomass, including agricultural residue and waste, have been seen as central to the pursuit of producing biofuels for vehicles, underlining an emphasis on sustainable use of agricultural inputs including arable land and water. The Government of India (GoI) resolution of 2002 explicitly recognised the objective of promoting biofuels as 'to give {a} boost to {the} agriculture sector and reduce environmental pollution', and reiterated the role of agriculture and agricultural land in the establishment of the 'biofuel complex' (MPNG, 2002). In 2003, the committee constituted by the Planning Commission on the development of biofuels in India noted that '(a)mong the various competing processes, bioethanol from lignocellulosic biomass appears to have economic potential. Crop residues such as rice straw, bagasse etc. are not currently used to derive desired economic and environmental benefits and thus they could be important resource base for bioethanol production' (PC, 2003). Subsequently, the National Policy on Biofuels 2009 had also emphasised the importance of using agricultural and similar wastes and supported developing biofuel production trajectories from lignocellulosic biomass. The 2009 policy had committed to undertake '(i)ntensive R&D work … for first generation biofuels and emerging technologies for second generation biofuels including *conversion of ligno-cellulosic materials to ethanol such as crop residues, forest wastes and algae, biomass-to-liquid (BTL) fuels, bio-refineries*, etc. (emphasis supplied)'[2] (MNRE, 2009).

Belying the possible impression from these policy documents that an emphasis on waste-based approach of deriving energy from cellulosic biomass is a recent trend, S&T institutions in India have had a long engagement with research on 'wastes and residues of agriculture'. These engagements were non-linear and witnessed constant shifts and repeated reframing of the agriculture, waste and energy discourse in India. Conventional accounts of biogas development for rural India

include endeavours to incorporate agricultural waste such as rice and wheat straw, even as the narrative of traditional source of animal dung dominated endeavours on biogas production in India. The *kachara* gas plant (*kachara* denoting garbage or waste) developed by Goswami and Choudhary in the 1960s, was a 'straw-biogas plant which can compete with the existing gobar gas plant' (*gobar* denoting cattle dung; Goswami, 1989). By emphasising the heterogeneity of the waste available for rural households, they reframed the problem of biogas to energy in terms of the types of available inputs:

> Biogas has been produced hitherto only from cow dung, but sufficient cow dung is available only to the rural rich. Seven or more cattle head required for a supply of dung for a family size digester are owned only by about 8% of rural families. Therefore, fibrous plant wastes must constitute the raw material for biogas. (Goswami, 1989)

This shift to agriculture, waste and energy in the discourse was sought through arguments about the 'appropriate technology' that shall cater to social conditions of surplus waste available for rural households with marginal resources.

Explorations to utilise residual agriculture biomass was not however limited to the production of biogas. A report prepared at the Indian Institute of Technology (IIT) Delhi in 1979, reviewing the status of biochemical engineering education and research in India during the period of 1958–1978, hinted at other R&D trajectories. Various projects listed in the report indicate early efforts to use agricultural wastes for production of biofuels at an industrial scale, including 'production of ethanol from bagasse hydrolysate by rapid fermentation technique' at IIT Delhi; 'alcohol from starchy material from jackfruit seed and shatti tuber' at Jadavpur University; 'alcohol from cellulosic wastes, acetone-butanol from molasses' at HBTI Kanpur; and 'development of fast fermenting yeasts for fermentation of molasses to alcohol' at Haryana Agricultural University (IITD, 1979). Professor T. K. Ghose, then a faculty at IIT Delhi, is considered a pioneer in India who emphasised the significance of cellulose as an alternative energy source. He established the 'Biochemical Engineering Research Centre' (BERC) at IIT Delhi in 1976, in collaboration with the Swiss Federal Institute of Technology, Zurich. In February 1977, BERC organised India's first international course-cum-symposium on 'Biochemical Engineering and Bioconversion of Cellulosic Substances into Energy, Chemicals and Microbial Protein'. BERC was by then recognised as a key research centre by the National Steering Committee on 'Fuels from Biomass' constituted in 1978 by the Department of Science and Technology (DST), GoI. Major DST-sponsored research projects undertaken by BERC in the 1980s included (a) microbial conversion of methane to methanol and (b) bioconversion of cellulosic wastes to ethanol. Even at the global level, 'BERC was the first to publish results of studies on ethyl alcohol {ethanol} from cellulose as an international communication' (IITD, 1980).

An important factor that globally sustained R&D to produce biofuel was the oil shocks of the 1970s. In the USA, President Nixon launched 'Project Independence'

in 1973 to establish energy self-sufficiency by 1980. Responding to the second oil shock, President Carter signed the Energy Security Act in 1980, which gave a major fillip to alternative energy research in the USA. In India too, as Maheshwari explained,

> The circumstances defined the research problem. Because of the oil crisis following the 1970 Gulf War, the funding agencies were soft on projects on bio-conversion of cellulosic 'wastes' such as rice and wheat straw, stover (leftover maize leaves and stalks after harvest), bagasse (leftover fibrous waste after extraction of juice from sugarcane), waste from paper mills etc., into alcohol. (Maheshwari, 2008)

Nonetheless, a cost-effective way for pre-treatment and enzymatic hydrolysis of lignocellulosic biomass for conversion into simple fermentable sugars has remained elusive due to the basic gaps in attendant scientific understanding. Following global cues, however, the S&T research efforts for converting lignocellulose into ethanol in India had subsided by the late 1980s. As Maheshwari commented: 'Though eager to solve the fuel problem, many researchers were forced to shift focus elsewhere until molecular biology tools had become sophisticated, sequence resources were to become available and plants with reduced lignin could be produced' (Maheshwari, 2008). It is only through the last decade that such tools were developed, prominently within the framework of synthetic biology approaches, towards production of biofuels from agricultural residue and waste.

Bureaucratic Incentives Towards Deploying Biofuel Technologies

There has been significant bureaucratic push to deploy first-generation ethanol and second-generation biodiesel technologies, including through the setting of targets of biofuel-blended vehicular fuels in the market. A prominent example is the Ethanol Blended Petrol (EBP) programme of the GoI that has required minimum procurements by the Oil Marketing Companies (OMCs). In September 2002, GoI directed that petrol blended with 5 per cent ethanol shall be sold in nine specified states and four union territories, with effect from January 2003 (MPNG, 2002). The scope of the EBP programme was expanded in 2006, whereby the GoI directed the OMCs to sell a similar blend of ethanol and petrol in twenty specified states and four union territories with effect from November 2006, 'subject to commercial viability' (MPNG, 2002). In January 2013, GoI directed the OMCs to '(s)ell Ethanol-blended-petrol with percentage of ethanol up to ten percent … to achieve five per cent ethanol blending across the Country as a whole' (MPNG, 2013). Earlier in December 2009, the National Policy on Biofuels had already set '(a)n indicative target of 20% blending of biofuels, both for bio-diesel and bio-ethanol, by 2017' (MNRE, 2009). It is revealing that Indian sugar mills only supplied about 665 million litres of molasses-derived ethanol[3] to the OMCs to be blended in vehicle fuel during the financial year 2016–2017 (Reuters, 2017).

A recent study conducted by Sujata and Kaushal demonstrates that, '(a)t present the preparedness is not there to achieve even a 5% blend nationwide, let alone 20%' (Sujata & Kaushal, 2017). This, the study reiterated, is largely because India heavily relies on 'first-generation' biofuels; primarily ethanol derived from molasses (a by-product in sugar industry that is also used as an ingredient in human food, cattle feed, and dietary supplements). A 2012 policy paper by ICAR's National Centre for Agricultural Economics and Policy Research, suggested that '(b)oth production and area under sugarcane will have to be more than doubled to achieve 10 per cent blending target' set for the EBP programmes, if these programmes were to exclusively rely on molasses derived ethanol (Raju et al., 2012). Such a strategy of doubling production and production area would be unsustainable as it will lead to substantial change in the pattern of land use and increased pressure on water tables given the water-intensive nature of the crop. Globally, varieties of feedstock are used for production of bioethanol including corn in the USA, sugarcane juice in Brazil and beet in some European countries. However, reliance on food crops grown on arable land starkly brings into play fuel vs food security debate in India. Use of first-generation biofuels is therefore not seen as a feasible and sustainable strategy for a country like India, underpinning the gaps in attempting the development and deployment of petrol blended with ethanol derived from molasses. Thus, it is apparent that the EBP programme has not achieved anywhere near its identified targets until date.

The inability in reaching similar targets in the development and deployment of biodiesel is even starker. In April 2003, the report of the committee on development of biofuel constituted by the Planning Commission recommended the launching of a National Mission on Bio-Diesel with the objective of achieving blending of high speed diesel (HSD) with 20 per cent biodiesel by 2011–2012. The committee proposed a large-scale plantation programme of *Jatropha curcas*, over an estimated 11 million hectares of waste and degraded land in and around forest areas. The report contended that

> (t)here are many tree species which bear seeds rich in oil. Of these some promising tree species have been evaluated and it has been found that there are a number of them such as *Jatropha curcas* and *Pongamia Pinnata* ('Honge' or 'Karanja') which would be very suitable in our conditions. (PC, 2003)

The non-edible oil seeds of *Jatropha curcas* were recommended as feedstock source for production of second-generation biodiesel[4] in India. The proposal envisaged a first phase by 2006–2007 to demonstrate plantation and cultivation on 0.4 million hectares. A self-sustaining expansion of the programme from 2007 was envisaged as a second phase to achieve a 20 per cent blending target by 2011–2012.

Several states including Tamil Nadu, Karnataka, Rajasthan and Madhya Pradesh actively responded to the proposal and initiated establishing Jatropha and Pongamia plantations. Various commercial entities too undertook this grand vision of establishing plantation for biodiesel over vast tracts of land; including Reliance Life Sciences, the Chhattisgarh State Renewable Development Agency (CREDA),

Indian Oil Corporation Ltd (IOCL), Hindustan Petroleum Corporation Ltd (HPCL), Bharat Petroleum Corporation Ltd, D1 Williamson Magor Bio Fuel Ltd (FE, 2005; Modi, 2007; Singh, 2008). However, none of these endeavours have succeeded. In March 2017, the Cabinet Committee on Economic Affairs approved closure/winding up of IOCL and HPCL joint venture companies with CREDA (since they are public sector companies). The official GoI communiqué noted '(d)ue to various constraints such as very poor seed yield, limited availability of wasteland, high plantation maintenance cost etc. the project became unviable and Jatropha plantation activities were discontinued' (PIB, 2017). By 2017, India's Jatropha-based ambition to introduce large-scale biodiesel blends had met a spectacular failure.

Beyond the chiasmic gap between targets set for deployment of these two technologies and its realisation, its deployment have also been generally recognised as unsustainable and unfeasible in recent years (PIB, 2017; Raju et al., 2012; Sujata & Kaushal, 2017), notwithstanding bureaucratic incentives and directions. In both these instances, concerns about environmental sustainability, food security and the social viability of diversion of land and other resources essential for food production are evident. The National Policy on Biofuels 2009 sought to address these tensions by affirming that '(i)n {the} future too, it would be ensured that the next generation of technologies is based on non-food feedstocks' (MNRE, 2009). In the case of diesel (which has higher annual consumption rate in India compared to petrol), introduction of biofuels has proved even more intractable. Beyond insider consultations, deliberations through formal public fora are almost absent in these bureaucratic attempts to direct first and second generation bio-fuel research. The pursuit of national interest and energy self-sufficiency in the vehicular fuel policy through development and deployment of biofuels also includes a stated policy preference for ecologically sustainable trajectories of bio-fuel production that shall use agricultural residue, as opposed to divert scarce resources of land and agricultural inputs that are currently used to produce food.

It is in these contexts of spectacular gaps between stated targets and the deployment of the first- and second-generation biofuels steered by the policymakers that the current bureaucratic direction of R&D in biofuel towards synthetic biology approaches needs to be placed. The Department of Biotechnology (DBT) is spearheading a major energy biosciences R&D programme in the country to realise the goals set in the National Policy on Biofuels. The Vision 2020 document, discussed in the next section, which is the new compass for the DBT and aims at development of next generation biofuels was prepared through a consultative process restricted to an expert group of scientists. Through these shifts, attempts at public engagement have been minimal, and the wider participation to guide the bureaucratic direction of R&D scant.

Synthetic Biology in Biofuel Technologies

The focus on development and deployment of biofuels in India and elsewhere has shifted to synthetic biology approaches in the last decade. The 'Bioenergy Road

Map Vision 2020' prepared by the DBT in 2012 explicitly aimed at 'producing new biofuels through synthetic biology' (DBT, 2012). The shift has to be placed within the context of the general recognition of the unsustainability and non-feasibility of the previous generation of biofuel technologies.

This shift was facilitated through a series of policy measures, and collaborations with the industry in India, and elsewhere. In an editorial for *Science* in June 2006, Chris Somerville emphasised the necessity of considerable resources to establish a cellulosic biofuel industry: '(i)t may be necessary to create a mission-oriented project similar to the Manhattan Project' (Somerville, 2006). Endorsing his views, Donald Kennedy, Editor-in-Chief of *Science*, suggested that the best course would be to abandon endeavours to derive ethanol from corn and sugarcane or biodiesel from palm oil (i.e., first-generation biofuel) and instead singularly focus on conversion of cellulosic biomass into biofuels. But he also reiterated the technical challenges attendant in this shift: '(p)lant lignins occlude the cellulose cell walls; they must be removed, and then the enzymology of cellulose conversion needs to be worked out', a technical project that lost bureaucratic support in the 1980s' (Kennedy, 2007).

The technical challenge was now pursued through a series of collaborations with the industry and universities. An early response was through a large industry–academia collaboration, whereby the oil-major Bharat Petroleum committed $500 million for research in bioenergy over a decade, in 2007. This collaboration established the Energy Biosciences Institute (EBI) in partnership with the University of California, Berkeley, the University of Illinois Urbana–Champaign and Lawrence Berkeley National Laboratory early the next year (Sheridan, 2007). The EBI, under the leadership of Chris Somerville, had the synthetic biology pioneer Jay Keasling also on board as the programme coordinator. He successfully advocated the use of cellulosic sources for production of cheap 'advanced biofuels', as a shift away from the approach of blending bio-ethanol towards developing advanced drop-in[5] biofuels. Whereby the EBI affirmed that '[s]ynthetic biology is a core function with the EBI'. In 2007, the U.S. Department of Energy (DoE) also announced an investment of $375 million to create three new bioenergy research centres (BRCs). Samuel Bodman, then US Secretary of Energy, had written: 'The challenge before us is to develop a new generation of biofuels – fuels made from cellulose, algae and other non-food products, and fuels that are compatible with the existing energy infrastructure like renewable diesel' (Yarris, 2008). The Joint BioEnergy Institute (JBEI), the BioEnergy Research Center and the Great Lakes Bioenergy Research Center were inaugurated in late 2008 with DoE funding.

In India, the DBT has run a dedicated 'energy bioscience' programme. In response to initiatives on biofuels in the USA, former DBT Secretary M. K. Bhan launched India's first bioenergy centre at the Institute of Chemical Technology (ICT), Mumbai, in December 2008; with an initial funding of ₹250 million (about $5 million; Lali, 2016). Subsequently, the DBT roped in an industrial partner (through an MoU with Indian Oil Corporation Ltd. in August 2011) to establish a second bioenergy centre at Faridabad with an initial cost of ₹530 million (about $10 million; IOCL, 2011). In March 2012, a third bioenergy centre was established

by DBT at the International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi. A Pan-IIT bioenergy centre, as a virtual centre was set up in 2015 to establish the fourth DBT bioenergy centre, which consists of 32 investigators affiliated to different Indian Institutes of Technology (IITs) at Bombay, Kharagpur, Guwahati, Jodhpur and Roorkee (PIB, 2015). More than 100 lead scientists in India were brought together through these four DBT bioenergy centres to support R&D efforts towards development of cost-effective next generation biofuels, demonstrating the substantial material and human investment by bureaucratic policymakers in the development of this specific trajectory of biofuels production.

Among the prominent objectives to establish these DBT bioenergy centres were 'develop technology for second generation bio-fuel' and 'perform cutting edge research using Synthetic and Systems biology approaches towards the development of novel technology for bio-fuel production' (PIB, 2014). Synthetic biology approach has thus come to occupy a key role in biofuels R&D in India. That the DBT energy bioscience is the only structured programme in India that specifically funds synthetic biology research is also a significant indicator of the preference for such a trajectory among the policymakers. The synthetic biology approach for research in second generation biofuels has been directed at (a) bioprospecting novel enzymes and engineering microbial platforms for its non-native production, (b) to engineer microbes for fermenting pentose sugars present in agricultural lignocellulosic biomass that cannot be fermented by traditional yeast, (c) engineer E. coli that can ferment glycerol, a low-value by-product of biofuel industries, into fuel compound like ethanol and (d) engineer E. coli strain for biological conversion of short chain fatty acids into various advanced drop-in biofuels including butanol. Synthetic biology approaches have also been applied towards third-generation biofuels including (a) altering microalgae for enhanced fatty acids and lipid production and (b) engineering cyanobacteria (blue-green algae) for biofuel production.

Scientists at the EBI and BRCs in the USA have carried out significant degrees of genetic modification in alternative feedstock such as switchgrass and sorghum in order to produce more sugars and less lignin. Further, microbes that can produce drop-in biofuels using these GM feedstock were also developed through extensive genetic modification. Synthetic biology approaches have played a key role in engineering metabolic pathways, for instance, in creating microbes that can make isopentenol (a petrol/gasoline replacement), bisabolene (alternative to diesel) and pinene (a precursor to jet fuel; Temple, 2018). Nonetheless, technical problems still persist. The original proponents are still in business but more sanguine: Chris Somerville of the EBI concluded, 'Our summary opinion about the state of technology for lignocellulosic biofuels is that important problems remain unsolved but the field has made substantial and underappreciated progress in the last decade' (Youngs & Somerville, 2017). Similarly, Keasling, who continues to head the JBEI, acknowledged: 'we probably underestimated it and probably oversold it, too' (Temple, 2018).

India too has not achieved any cost-effective demonstrable success in its effort to produce second- and third-generation biofuels using synthetic biology approach.

However, DBT-ICT centre at Mumbai has developed a novel 2G-ethanol technology for lignocellulosic biomass, which uses patented pre-treatment processes capable of turning any agricultural residue feedstock into ethanol, with claim of low capital and operational expenditure (Lali, 2016). A demonstration-scale plant built at a cost of ₹350 million (about $5.2 million) was inaugurated in 2016. According to the Ministry of Petroleum and Natural Gas, 'Oil PSUs … are planning to set up twelve (12) 2G Ethanol Bio-refineries across 11 States …. The estimated investment for the 12 Bio-refineries is ₹100 billion'[6] (PIB, 2016). Large-scale infrastructures are being instituted even as the earlier significant installations like Jatropha plantations are being dismantled. Further, the DBT-coordinated Indo-US Joint Clean Energy Research and Development Centre (JCERDC) and associated Biofuel Consortium has identified high biomass sorghum, pearl millet and bamboo as sustainable feedstock for advanced lignocellulosic biofuels (DBT, 2016). Synthetic biology-driven low lignin feedstock strategy may thus push for cultivation of GM sorghum in India. On the other hand, third-generation biofuels derived from micro and macro algae through a synthetic biology route would demand large-scale onshore and offshore cultivations. These developments can not only significantly shift agriculture, waste and energy discourse but also substantially alter agricultural practices in India. In this context, the recently approved National Policy on Biofuels 2018 notes that '(s)ustained and quantum non-availability of domestic feedstock for biofuel production … needs to be addressed' (PIB, 2018). Making a major shift by categorising food surplus as raw material '(t)he Policy allows use of surplus food grains for production of ethanol' (PIB, 2018). The 'biofuel complex' through synthetic biology-driven R&D and policy measures is therefore likely to reframe agriculture and energy discourse, affecting the public at large.

The potential impacts on ecological and agricultural spheres, including on millions of farmers and farm labourers, diversion of 'surplus food grains', introduction of GM food crops deemed technically necessary for the new generation biofuel technologies to work and effects related to on/off shore cultivation of algae are significant. However, there has been scarce attempts at public consultation or public engagement regarding the research trajectories on biofuel that should be pursued in India. The considerable gaps between stated targets of technologies and the inability to translate them during their deployment, in the previous generation of technologies, did not result in wider public engagement exercises. Given the emphasis on wider public engagement exercises in RRI frameworks, whether an explicit engagement with RRI frameworks may have persuaded policymakers to elicit guidance through public engagement exercises on how techno-bureaucratic spheres steer the development of S&T on biofuels in India is a moot point.

Responsibility, Representation and Participation in Research and Innovation

It is in the context of considerable gaps between directed development targets and the relatively negligible extent of deployment of earlier biofuel technologies (be it the blending of petrol with molasses-derived ethanol or the establishment of large

scale Jatropha plantations for biodiesel), as also recognition that they are unsustainable and non-feasible, that the current bureaucratic steering of biofuel production through synthetic biology approaches needs to be placed. Bureaucratic steering of research and development in the aforementioned technological trajectories in biofuels has been carried out through specific combinations of science and policy—where prescriptions in formal policy documents are combined with incentives to conduct scientific research in specific trajectories through grants, facilitation of private–public and industry–university collaborations, and setting of targets of consumption of downstream products—aimed at establishment of 'biofuel complex'. What is the notion of responsibility that can guide the bureaucratic steering and establishment of the biofuel complex would then require considerable attention.

The values and goals that can be identified in this bureaucratic direction of R&D for the production of vehicular biofuels in India are threefold. First is a goal of achieving national self-reliance in vehicular fuel production, including through import substitution of crude oil and second is food security in terms of securing the food production system in a way that scarce land and other resources be not diverted from it for the production of fuels. A third broad goal approximates within a notion of sustainability that also seeks to find a workable balance between the earlier two goals.[7] At the same time, public deliberation and reflection about the desirability of pursuing the development and deployment of biofuel technologies is nowhere mentioned in policy documents. In addition, a public evaluation comparing the different available technological trajectories for production of biofuels, an evaluation that elicits and engages with the wider public appears absent. Even as it cannot be argued that public engagement (or for that matter employment of any other RRI principle) could have definitely avoided the current situation, the lack of engagement and any explicit institutional reflection merits further attention. No institutional reflection, regarding the process through which prior decisions to develop and deploy attendant technologies were taken, is publicly available; even in spectacular failures like the institution of Jatropha plantations for production of biodiesel, where substantial material and human resources were brought together in a large scale.

The only process that explicitly claimed to have been an outcome of a public engagement was the report of the committee on development of biofuel (constituted by the Planning Commission) in 2003, who had originally proposed the large-scale Jatropha plantations. There was a brief mention in the report that 'the concept and the project profile of the National Mission on Bio-diesel has been the outcome of an intensive consultation process with the various stake holders, namely the automobile manufacturers, the farming community, NGOs, concerned Central & State Government Departments and research bodies' (PC, 2003). The enthusiasm exhibited in the report for the plantation is belied by vocal concerns expressed by the civil society, and sobering warnings from experts (Fairless, 2007). Questions about the gaps and failures related to the earlier generation technologies—were they due to the manners in which these technologies were deployed, or were they flawed in its conceptualisation, were there wrong/inaccurate/inadequate factors

attendant to the way technical consideration were evaluated, or were the important attendant social conditions not identified or understood—are conspicuously absent within institutional processes. Engaging with such questions is not only important to understand the reasons for failures of technologies that are developed but are also crucial steps in a process that precedes subsequent bureaucratic direction of technologies, and governmental bodies have a responsibility to ensure such processes. Nevertheless, scant institutional reflection is available about the grand and confident assumptions that led to the bureaucratic direction that preceded failures like the institution of Jatropha plantations, or regarding the fundamental material limitations in the attempts to produce bioethanol in large scale from molasses.

Much apart from the possible engagement with the RRI framework, a certain degree of (legalistic notions of) responsibility for certain kinds of governmental action to be preceded by public consultations and hearings exists in India. Prominent here is a legal expectation to conduct public consultations and/or hearings for impact assessments before regulatory decisions for specific projects are made, say environmental clearances for developmental projects (MoEF, 2006; Thayyil, 2014). There are also examples of public consultation (albeit far and few) before decisions on specific technological trajectories are taken, beyond the aforementioned eliciting of views of the affected communities or general public before the green signal for a specific downstream project is granted. Public consultations ordered by the then Union Environmental Minister Jairam Ramesh in 2010 before a decision on the environmental clearance for the use of Bt Brinjal is a prominent example. Further, Technology Information Forecasting and Assessment Council (TIFAC) claims to have undertaken a wider public engagement process before the preparation of Technology Vision 2035 document (TIFAC, 2015; but see further on this Sekhsaria and Thayyil [2019]).

The bureaucratic direction of research and innovation that preceded development of both first-generation biofuel research and the current synthetic biology-based approaches appears similar in its absence of wider public engagement, reflection and deliberation, and contrary to the spirit (if not the letter) of the aforementioned legalistic notion of responsibility of public consultations. The absence of public evaluations of the failures of prior bureaucratic direction in the development and deployment of earlier technologies raises questions about the process of decision-making in the current promotion and championing of synthetic biology approaches to produce biofuels. The current move in the National Policy on Biofuels 2018 policy to categorise food surplus as a raw material for biofuel, in a country that is at the bottom of world's nutrition and hunger charts, brings back the concern visible in the fuel vs food security debate. If one were to recognise the hybridity of the construction of next generation biofuels, at the interface of science and policy, different constellation of norms that reside in RRI frameworks—be it *anticipation*, *inclusion*, *reflexivity* and *responsiveness* (Stilgoe, Owen, & Macnaghten, 2013) or *anticipation*, *reflection*, *engagement* and *action* (Owen, 2014) are readily identifiable. Whether such arguments for institutionalising an idea of responsibility that is prospective in nature, 'recognizing profound uncertainties and encouraging

and supporting researchers to join intellectual forces to explore them' (Stilgoe & Guston, 2017), would be found helpful by policymakers is yet to be seen.

Whether the absence of any serious public process before important decisions like bureaucratic direction of synthetic biology research approaches in the production of biofuels, or invocation of the aforementioned rare instances, can spur moves to institutionalise wider 'upstream' engagements to open up innovation process (Stirling, 2008) in India needs a more engaged political analysis. So does the question of realism of such engagement processes becoming part of a cynical legitimating exercise. If we take Winner's prescient reminder of 'no innovation without representation' seriously (Winner, 1993), prospective ways to institutionalise processes of broad public engagement that guides bureaucratic direction of technological trajectory through a mixture of science and policy become crucial. And yet in what ways can the apparent inability of policymakers to reflexively pose questions about their prior decisions lead to institutionalisation of specific forms of public deliberations, including about the desirability and appropriateness of the current turn to synthetic biology in biofuel technologies, would need further attention.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

FUNDING

Mahendra Shahare acknowledges the Indian Institute of Technology Delhi for the doctoral research fellowship.

NOTES

1. In colonial India, during World War II, a law mandating 20 per cent power alcohol blending was introduced in the year 1940 by the United Province (today's state of Uttar Pradesh). The term 'power alcohol' denoted ethyl alcohol (ethanol), derived from sugarcane molasses.
2. Biofuels derived from food sources such as corn starch and sugarcane juice or edible oils are classified as *first generation biofuel*, while *second generation biofuel* refers to biofuels manufactured from non-food feedstock such as agricultural waste or non-edible oilseeds.
3. Since molasses is not a waste product, requires similar processes that are used in sugarcane or starch based ethanol production, and is not a cellulosic biomass, broadly ethanol produced from molasses is categorised as a first generation biofuel.
4. About half of India's domestic demand of edible oils is met through imports. Production of first generation biodiesel using traditional feedstock such as soybean or mustard (rapeseed) is thus not considered as a viable option.
5. Biofuels like ethanol are used as blends but not as complete substitutes because that necessarily requires modifications to existing petroleum infrastructure such as pipelines and engines. Thus ethanol use is restricted by blending limits. Whereas advanced drop-in biofuels are equivalent to prevalent petroleum fuels and hence can be used as substitutes without blending limits or infrastructure modifications.

6. Approximately $1.48 billion.
7. In addition, the recent National Policy on Biofuels 2018, lists expected benefits in biofuels such as health benefits, MSW management, infrastructural investment in rural areas, and employment generation and additional income to farmers.

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Consensus or Contestation: Reflections on Governance of Innovation in a Context of Heterogeneous Knowledges

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Governance of innovation needs to cater in a democratic way for heterogeneity of knowledges. Many initiatives in the democratisation of innovation aspire to some sort of consensus among relevant actors. However, consensus tends to silence dissenting voices, typically those of marginalised groups. In situations of high epistemic and epistemological diversity, this problem can be expected to aggravate. Against consensus-seeking theories of deliberative democracy, Chantal Mouffe has proposed the aspiration to grant the possibility of contestation. While one central principle in many theories of democracy is that it should never silence dissenting or minority positions, Mouffe elevates contestation, rather than the pursuit of consensus, to be the linchpin of democracy. I will explore what a contestation-oriented view of democratisation could mean in the case of governing innovation, specifically in the case of biogasification of rice straw. The latter is commonly presented as a potentially beneficial use of rice straw, which is currently considered waste and (illegally) burned by farmers on the Indian countryside. However, our research has shown that this view indeed unduly suppresses valuable yet marginalised knowledges. Lessons for frameworks such as Responsible Research and Innovation, and particularly an alternative to the dominant aim of democratising innovation through deliberation, will be drawn.

Keywords: Contestation, knowledge brokerage, Responsible Research and Innovation, epistemological diversity

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Acknowledgements: The author is indebted to four anonymous reviewers of this journal, and to (in counteralphabetic order) Amelie Riedesel, Poonam Pandey, Annapurna Mamidipudi and Wiebe E. Bijker for the collaborative fieldwork that inspired this paper.

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Science, Technology & Society 25:2 (2020): 341–356
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0971721820903005

Introduction

Thinking through innovation has a long history, and moreover one that has long been concerned with issues of democratisation. Innovation is essentially about making new things or making things new, regardless whether we talk about products (both artefacts and services), processes, the ways things are positioned and the mental models we use to manage things (Tidd & Bessant, 2009). That innovation potentially has a democratic deficit is not hard to see. When innovations have consequences that pervade into the broader social world, people who are not directly involved in the innovation process may yet experience its consequences. Acquiring access to that process, and exerting influence, is easier for those who have formal expertise and socio-economic power than for those who lack these assets. Being forced to experience the consequences of innovations in which one has no say constitutes a democratic deficit that calls for democratisation.[1]

Democratisation of innovation is not least about improving the inclusion of knowledges that are somehow relevant, while yet hitherto excluded from the innovation process. Most prominently, this is the case when they are not recognised as formal expertise. Presumably, inclusion of these knowledges is desirable either for reasons of democratic legitimacy or for reasons of prudence, when there is something valuable in the unheard knowledges. The working hypothesis underlying this article is that such democratisation of innovation by inclusion of knowledges is more difficult in situations of higher epistemic and epistemological diversity; that is, diversity in what people think about things and diversity in how people validate their knowledge. I assume this as a general structure: Some parties have a stronger hand than others in the innovation process, which means that they also have a stronger hand than others in determining what knowledge is deemed relevant. Knowledge that is closer to those dominant parties' criteria of validation thus has a greater chance of being included in the innovation process. In situations of higher epistemological diversity, where knowledge validation systems are more apart, this will play out as a bigger hurdle for knowledge to travel, especially for subaltern knowledge.

The incorporation of knowledges other than formal expertise into innovation has inspired a whole range of inclusion initiatives. These range from consensus conferences, stakeholder meetings and technology assessment (Van Est & Brom, 2012) as a specific form of expertise that informs parliaments to organised nation-wide debates such as the *broad societal discussion*[2] on nuclear energy in the Netherlands in the 1980s (Hagendijk & Terpstra, 2004). The recent discourse on *Responsible Research and Innovation* (RRI) is to be reckoned a novel branch to this tradition. It specifies a number of concrete aspirations for this democratisation: innovation should be anticipatory, inclusive, reflexive and responsive (Owen, Macnaghten, & Stilgoe, 2012; Schomberg, 2011; Stilgoe, Owen, & Macnaghten, 2013).

Ultimately, much of this strategy is aimed at reaching consensus and the straightforward, uncritical incorporation of knowledge (Van Oudheusden, 2014). This is not surprising, as a univocal position offers a much more productive action perspective than a controversial one does. This means that innovators are likely to

value unambivalent more than ambivalent knowledge. In a classical political theory such as John Rawls's (1993), consensus is not so much the opinion that all members of a community hold, but rather a conclusion that the vast majority of a community can accept, because it has been achieved after due, democratic process undisturbed by power relations (even if they, as individuals, may disagree to its content). Yet it is worth noting that any consensus is relative to the circumstances in which it came about (Harding, 2009). This entails that the content of the consensus will be subject to dominant epistemologies, even if it is pretendedly neutral: knowledge positions will be easier to justify if they comply with dominant ideas of such justification.

In consequence, consensus is potentially hostile to deviant opinions, especially if those opinions are backed by epistemologies that are not acceptable across the community, or at least the dominant part of that community. While it is at the basis of democratic theories that dissenting opinions should not be silenced (Mill, 1991 [1859]), such a thing is easier said than done. Voices speaking from minority epistemologies, by definition, run the risk of appearing as nonsensical or irrational at worst, and uneducated and uninformed at best. Hence, even if they are granted the right to speak, there is still no guarantee that their input will sort any effect.

In this article, I will therefore develop ideas on how such emancipation of minority voices can be shaped further. I build on the work of, amongst others, Chantal Mouffe, who proposes *contestation* as a better principle for organising politics than *consensus*. Chiefly, the idea is that people should be enabled to publicly contest the validations of other knowledges, notably those knowledges of which the validations have come to be accepted as natural to the community. Of course, in practice, discourse is not this black and white. There are higher and lower degrees of agreement, higher and lower degrees of similarity in validation and justification, and higher and lower degrees of social inclusion in decision-making processes. In practice, consensus and contestation will both have some legitimacy at specific points. What matters here is that the contestation part requires further development.

This article engages with such difficulties specifically in the context of innovation. To complex innovation projects, many different sorts of knowledge are (potentially) relevant. Yet their inclusion is non-trivial if particular epistemologies are dominant. In times where the call for *RRI* (Owen et al., 2012; Schomberg, 2011; Stilgoe et al., 2013) with further pleas for knowledge inclusion are well heard, this problem merits due attention. How can we build a knowledge-inclusive way of governing innovation?

This article builds on 1.5 year of research into the problem of rice straw burning on Indian farmlands, notably in the states of Punjab, Haryana and Uttar Pradesh, and biogasification as a potential solution. Initially, shaped as an RRI study to help shape an innovative technology in an inclusive way, the project gradually shifted to a study into the intricacies and ramifications of the problem of rice straw burning. In a nutshell, the case is that farmers alternatingly grow wheat and rice on the same land. They need to vacate the land off rice residues quickly so as to be able to sow the wheat. Burning the residues on-site is often felt to be the only solution. Our initial engagement with the problem came from the innovative idea of using

the rice straw for the production of biogas, an innovation project in which chemical industrial corporates would have to collaborate with farmers.

On the one hand, we noticed that a lot of relevant and valuable knowledge was available among the different players. This knowledge was in all its diversity highly relevant to understanding the problem of rice straw burning and any inventive solution to it. On the other hand, we noticed that knowledge failed to flow easily between the different players: They had radically different understandings of the problem, and even more so of the solutions that would be desirable. Below a seemingly defeatist stance among many with respect to the feasibility of cooperation, we found different, incompatible narratives, knowledge validations and value prioritisations.

The central claim developed in this essay is that if innovation in such situations with high knowledge heterogeneity wants to achieve technologies that are adapted to the contexts in which they are to operate, it had better build arrangements for *contestation* in addition to arrangements for *consensus building*. If left uncorrected, consensus building runs the risk of silencing knowledges from subordinate groups. Cultivating contestation, on the contrary, permanently allows all voices to speak, and to speak moreover from a position with more legitimated epistemic authority.

This article will continue along three lines. First, I will seek to make sense of such radically different knowledges and their epistemologies, and give each their due in a comparative[3] perspective. Second, I will explore how the aforementioned contestation can be achieved and productively sustained over time, in a way that makes sense to all involved actor groups. And third, I will propose arrangements for this contestation process such that it specifically caters towards innovation processes, where knowledge is not only heterogeneous but also tied to epistemic authorities that differ both in (perceived) level and kind of justification.

The Consequences of Consensus

Initiatives in stakeholder engagement, understood broadly, have sought many ways to broaden the knowledge base that innovation projects can tap into. This has been pursued for various reasons. As Reed (2008) reviews, participatory initiatives are variably justified by an appeal to the potential reduction of marginalisation, the breeding of trust in decisions and civil society, the empowerment of stakeholders to join in the co-production of knowledge, the facilitation of social learning and the presentation of decisions as being taken in a fair way and inclusive of a diversity of values and needs. Also, it is claimed that participation will help produce better decisions and decisions better adapted to local situations. Within *science and technology studies* (STS), one classical insight is that different groups will have different definitions of an innovation problem (Bijker, 1995). It is through their particular definition of a problem that groups are connected to the problem (Callon, 1986), and participatory methods should thus cater to a multiplicity of such definitions.

Even though thinking through participation has gone a long way in STS (see e.g., Chilvers & Kearnes [2015] for a recent overview), not all these promises are

delivered. It is observed that many current attempts at participation are limited to straightforwardly including actors and their opinions, without a clear idea of how the concurring politics should be facilitated and how mechanisms of inclusion and exclusion can be laid bare and repaired (Van Oudheusden, 2014). In some cases, the development of such initiatives comes down to mere window dressing, and in other cases it leads to an ever larger, uncritical inclusion of parties, without a clear justification or strategy and hence with unclear benefit for the innovation process (Gregory, 2016). But most important for the current argument are the hazards that majority knowledges remain hegemonic (Callon, Lascoumes, & Barthe, 2009; Fuller, 2012), and more specifically that techno-scientific expertise remains dominant (Guston, 2013).

Along these lines, the call for more reflexive approaches to participation has been increasing recently. For example, Wynne (2007) observes that participation processes are usually kept firmly in the hands of experts who thus impose their specific perspectives. Carrying this a step further, Voss and Amelung (2016) argue that participation methods have in fact themselves become objects of technocratic management, and thus ironically reproduce the very democratic deficit that they were intended to resolve. In response to this issue, Krzywoszynska et al. (2018) show how letting stakeholders co-determine the very *format* of participation (as opposed to surveying their perspectives in pre-set formats) leads to the articulation of entire novel rationalities. And Lezaun, Marres, and Tironi (2016) review that participation is today often shaped as experiments, so as to allow (amongst other benefits) new problem definitions to emerge.

It seems crucial that inclusion not only takes place at the level of knowledge, needs and values but also at the more reflexive level of questions such as where critique can be levelled, what format the participation should have and which problem exactly is to be solved by the inclusion. Exclusion is not only a de facto phenomenon of deviant opinions being harder to voice once a majority opinion has stabilised. According to Chantal Mouffe (2000), it is rather *in the very act of achieving consensus* that exclusion happens. As she discusses in the context of political philosophy, both John Rawls and Jürgen Habermas devise procedures (be it very different ones) to arrive at consensus. For both, consensus depends on specific norms and substantive content. This makes the consensus and even the procedures of consensus building inaccessible for those who cannot recognise these norms as their own. This would be no problem if the norms were truly universal, but the very possibility of universal norms should be approached with the deepest scepticism—if not from a normative perspective, then at least from the empirical observation of their failure to achieve general acceptance.

With Mouffe (2013), democratisation is about rendering dissenting voices in their own right. In contrast, both Rawlsian and Habermasian forms of deliberative democracy tend to see dissenting voices as something that needs to be accommodated and primarily protected against the tyranny of majority. They seek the legitimacy of the majority in neutral procedures (Rawls) or in power-free deliberation (Habermas), but do not problematise the epistemologies of majorities that themselves depend on power. It is key to Mouffe's ideas that this problematisation itself is democratised.

This cannot be enshrined into a single institution, as that would de facto become the new epistemological hegemon. Therefore, she proposes pursuing a multitude or 'ecology' of institutions that together cultivate this.

Thus, according to Mouffe (2005, p. 3), any pursuit of impartial institutions should be abandoned. Instead, we should seek arrangements that stimulate a vibrant public sphere, and more specifically, arrangements that explicitly facilitate agonistic debate: debates that are open to contestation, not only of achieved consensus but also the foundations and justifications on which such consensus rests. This entails that discourse should not be framed in terms of right or wrong, let alone the today obsolete categories of left or right. These categories are far too restrictive to conduct an agonistic debate.

I try to answer to this call specifically with respect to innovation in a context of heterogeneous knowledges. Some knowledges, chiefly those of policymakers and formal experts, are likely to be paid due attention in the innovation process. Others, such as craft knowledge and farmers' knowledge, are not. This is despite the fact that they have a certain pertinence to the innovation problem—the knowledge itself concerns the important context of application, and the owners of this knowledge have a clear stake in the innovation because of their rootedness in the context of application. It is also despite the fact that the knowledges are grounded in full knowledge systems; they just lack grounding in dominant knowledge systems. How can we make sure that these knowledges, while legitimate and relevant, yet not founded along the lines of dominant epistemologies, somehow remain able to stand their position in the innovation process? How can we make sure that voices that are not couched in the technocratic idioms of technoscientists and policymakers can somehow remain relevant and even recognised on an equal footing to technoscience?

Knowledges do not circulate independently, but are connected to specific social groups. Thus, the issue is not only about the inclusion of mere knowledge but also about how group identities are defined, and about which identities are found to be legitimated to speak. In our study, we have sought to understand knowledge identities as something achieved by a social group, rather than as something connected to some overarching, decontextualised standard of valid knowledge. Also, knowledge identities are thus not something readily available for political accommodation but something of which the legitimacy and 'right to speak' are achieved through work. In the context of RRI, and governance of innovation more broadly, this raises the question whether and how specific knowledge identities can and must be enrolled to contribute to the innovation process, and whether and how they can be enabled to provide a perspective on the legitimacy of competing—and potentially dominant—knowledge identities.

One final question is how this can be institutionalised, or otherwise perpetuated over time. Looking at the specific case of rice stubble burning, how could such agonistic knowledge exchange be installed more permanently? And how can knowledge identities be enabled over a longer period of time to conduct this

contestation in a public, political way? What this means for innovation and stakeholder engagement in the specific case of rice stubble burning and biogasification in India is what I will explore in the remainder of this article.

The Case of Rice Stubble Burning and Biogasification

As mentioned above, we[4] initially set out to conduct an RRI-inspired investigation into the possibilities to produce biogas from rice straw. In theory, this innovation would kill multiple birds with one stone. It would offer a more economical alternative of using the rice straw than the burning that farmers see themselves currently compelled to do as a consequence of intensive, industrial-style farming and quick crop rotation. It would also avail a great amount of energy from a renewable source to the national energy balance. It would, if remunerated, offer the farmers an additional source of income—what is now thought of as waste would become a commodity. And it would relieve vast parts of India, including the Delhi metropolitan area, of a major source of smog and air pollution.

The innovation was envisioned by an international corporate player, and they contributed in kind to our research. This innovation, as originally conceived of, entailed the challenge of making a connection between corporate players and farmers in question, many of whom are smallholders. In addition, the innovation had the interest of policymakers at many levels, of activist groups and researchers both in academia and in commercial research. Each of these groups has a different, preferred understanding of the problem. Of course, the groups are internally not as homogeneous as might thus be suggested, but the current small research project did not offer the opportunity to differentiate extensively here. Bringing together the various definitions of the problem and its potential solutions is a complex affair, when such a diversity of perspectives is in place.

In the course of one and a half year, we conducted interviews with over twenty experts, from corporate innovation, policymaking at various levels, academic research, social action groups and farming. The interviews were semi-structured and primarily aimed at elucidating the respondents' perspectives on rice straw, gasification and the problem of rice straw burning. In particular, we were interested to learn how they define the problem of rice straw (if any), and what solution they deem realistic. In addition, we also (co-) organised a number of events with various actor groups, some more heterogeneous and others less so. For example, we co-organised a meeting with about 100 farmers, which was comparably homogenous, even though farmers represented various farming paradigms, from organic to industrial farming (see also Mamidipudi & Frahm, 2020; Pandey, 2020). In contrast, we also organised a workshop where academics and policymakers attended, which was comparably heterogeneous. We provided a workshop to corporate scientists and engineers. And the final event welcomed representatives from all sorts of stakeholders.

Stakes were different for different groups, and we as researchers had stakes of our own as well. Initially, our commitment was to the gasification of rice straw

and the question how this can be implemented in a societally responsible way. In a way, we very much committed the sin of having our agenda determined by the innovation expert perspective, but it was all we had at that first moment. During the process, our engagement broadened, and we sought ways to also incorporate other definitions of the problem. For this article, I will allow myself to discuss only one cross section through the case as it emerged: the challenge of finding a way to treat different knowledges in a fair way, thus implicitly emancipating those problem definitions that would otherwise have difficulty getting heard and making a substantial contribution to the innovation process. In particular, how can it be that respondents from all groups succeed in explaining their particular definitions of the problem fairly clearly to us as researchers, while it is recognised across the board that communication between the groups is so hard? The explanation of India being a stratified and segregated society where groups simply do not talk to one another would be overly simplistic here, as it would dismiss the many structures and communications that run across different strata.

As a mode of inquiry, we sought to remain open to a multiplicity of problem definitions. To a large degree, this is a commonplace for researchers in STS. However, moving beyond straightforward perspectivism and carrying the multiplicity of problem definitions to all its consequences is a challenge of its own. For example, in discussions with stakeholders, we did not straightforwardly invite them to discuss their view on 'the problem of rice straw burning', but rather inquired carefully into what kind of challenges they perceived, what possible solutions they could think of and what was preventing them from realising those solutions. This led to them coming up with different primary problems: ranging from the problem of smog because of the burning to visions of the whole industrial approach to agriculture being bad, to logistical and supply-chain problems and to problems of poor education.

We could proceed with these multiple problem definitions because we addressed each of the groups separately. This provided a safe space where knowledge could be shared, and first corroborated within its own validation systems before we would take it out and confront it with other knowledges. We explicitly probed these validation systems by asking how people know things. We also provided explanatory examples ourselves of how we conceived of knowledge as being situated and dependent on local epistemologies. To holders of dominant (and often pretendedly universalist) knowledges, this offered a reflexive moment leading to some modesty and openness. To holders of subaltern knowledges, this offered a moment of validation and emancipation, and contributed further to the safe space for them to stage and own their knowledge. Also, it allowed for people to be critical of ideas on modernisation and progress, which are otherwise perceived as self-evident and beyond critique.

At the end of the project, we did not arrive at a clear-cut solution for dealing with rice straw, whether the burning part or the biogasification part. But we did achieve that voices could be heard that would otherwise have remained more silent. One important merit of our engagement was that this highlighted the complexity

and multiplicity of the rice straw problem, and helped make novel connections between knowledges and contexts. This point seemed to be well received by all parties, although we had no method to corroborate this.

The point made earlier, that democratisation of innovation (and more broadly democratisation of a knowledge society) needs to include a democratisation of the critiquing of knowledge, has been realised, though it needs our articulation to see it. Our intervention of bracketing knowledge and connecting it explicitly to its contextualised validation, implicitly opens it up for such contestation. At the same time, this contestation ran via us; not as a debate in which the contestants themselves actually engage in critiquing each other's epistemologies. This loads unto us the suspicion of taking an external position, a 'view from nowhere' or a 'God's eye perspective' if you like. I will seek a speculative answer to the question of how to resolve this in the next section.

While I stressed earlier that consensus is not to be pursued, it is vital for any strategy for innovation to somehow arrive at a form of closure: a sufficiently endorsed position on how to proceed. While we ended the project with substantive recommendations, these were at the same strategic metalevel as the current analysis: They concerned how to go about knowledge emancipation and problem articulation, etc. We did not achieve closure with respect to what to do with rice straw, what to think of biogasification, and what to do about the stubble burning and ensuing smog problems. We could not do that within the extremely short project duration, we did not pursue it and we felt this not to be our task. But it is something that knowledge brokerage, as proposed in the next section, will need a solution for—a solution that is at once worthy of the name closure and open enough to keep allowing for contestation.

Agonistic Pluralism in Governing Rice Straw Innovation

This special issue is organised around the theme of RRI in the Global South. Before I move on to speculating about how the above agonistic take on development could be developed specifically for a Global South perspective, it is crucial to take away some prejudices that might seep into the frame. For one thing, while smallholding farmers are vulnerable in important senses, we cannot treat them as a vulnerable group per se. It needs to be recognised that they have valuable coping strategies vis-à-vis the threats to which they are vulnerable. Also, treating them as categorically vulnerable would deny their innovative capacity and knowledgeability, which is in fact a crucial premise to the agonistic take on innovation. This is what I call the first principle: assume resilience and inventiveness, not misery (cf. Hommels, Mesman, & Bijker, 2014).

The second principle is of non-universal modernisation. We cannot treat the Global South (at any level, from individual citizens to entire states) as being on the same trajectory of progress as the West, just at a less-advanced point (Furlong, 2014; Hess et al., 2016, pp. 322–323; Robinson, 2005). Instead, we should somehow facilitate that owners of a particular future are themselves in charge of

setting the criteria for that future and the terms in which it should be discussed (cf. Krzywoszynska et al., 2018). This offers a methodological restraint to me as a (Western) researcher,[5] who will by definition remain susceptible to the pitfall of *orientalism* (Said, 1979). But it is also a core ingredient to the agonistic approach to innovation itself: emancipating owners of a future to let their own criteria speak to that future allows for hegemonic criteria, and naively universalised ideas of modernity, to be replaced by local, alternatives that are felt to be more appropriate.

Let me use this point, of allowing actors to set the criteria for their own futures, as a first entry into developing agonistic innovation. Sandra Harding (2001) warns against uncritically emancipating oppressed knowledges or distinctively non-Western ways of knowing innovation. All knowledges, including oppressed ones, inherit specific limitations as a consequence of their situatedness. Yet one tenet in *standpoint theory* (Harding, 2004) is that knowing from an oppressed position requires more work because it needs to achieve liberation from taken-for-granted epistemologies. This exactly enables oppressed positions to know the mechanisms of oppression better. An exemplifying problem is when crafts knowledge is dismissed because it has not been corroborated in the same ways as have scientific and engineering knowledges. This needs to be repaired, not only by simply staging the knowledge but also by staging the way it understands itself *as knowledge*, and the way it understands the other knowledges that dismiss it. This is the third principle: connect knowledges to their own epistemologies and emancipate knowledges and epistemologies in tandem.

The fourth principle then holds that for a fair and symmetrical treatment, it is not only vital that all knowledges can defend their legitimacy by appealing to their own epistemology; they should also be allowed and enabled to critique the epistemologies of others (cf. Visvanathan, 2009); or put in terms borrowed from *standpoint theory*, it is not only about including the excluded and their ways of understanding themselves but also about including their ways of understanding the excluding parties with their particular knowledge and particular social relations (Harding, 2009). For example, when straw-burning farmers are confronted with the idea to convert their rice straw into biogas, they must somehow be enabled, and actively facilitated, to speak about the fact that the whole way of thinking of scientists and policymakers evidently overlooks the injustice they feel is done to them: The onus of collecting the straw and availing it to industry is uncritically shifted to them, whereas in their own perspective, the straw is itself already something ‘done to them’ by the system of intensive farming they are locked into. To them, it is not something they are responsible for in the way envisioned by scientists and policymakers. The disagreement is not only about the facts and the question who owns the rice straw (or, for that matter, who is responsible for solving the problem of burning). It is also about the decontextualising (Feenberg, 2002) and universalising way of knowing of policymakers and scientists that supports the specific diagnosis, and that would be critiqued by the farmers.

In this specific case, of an innovation that is to meet a highly heterogeneous social reality, some arrangements could be put in place in order to secure that these

principles can be delivered. Some conditions are vital to such institutionalisation. The arrangements must be acceptable to all, which poses an additional challenge if power relations are also internalised by the subaltern, and their critical perspective might be hidden from their own view. The arrangements must be able to survive more or less independently of particular individuals and remain in place over a longer period of time. While the research we conducted cannot produce a fully corroborated recipe for such institutionalisation, at least it provides important lessons learned.

The arrangements needed are best captured under the notion of *knowledge brokerage* (Malinovskyte, Mothe, & Rüling, 2014; Martinuzzi & Sedlačko, 2016). In its most general sense, knowledge brokerage is the activity of translating knowledge from one knowledge system to another, so as to make it useful in other contexts. In a narrower sense, it is also understood as the particular translation of academic and scientific knowledge towards practices of politics and policymaking, with the aim of making an 'impact' on behalf of science. In view of this specific case of incompatible epistemologies, I connect the four principles mentioned above to three concrete recommendations for knowledge brokerage. The recommendations are variably connected to the four principles, not one-to-one.

First, it seems vital to differentiate and segment between different knowledge groups, so that each knowledge group can stake their claims to knowledge in a somehow protected space. While this whole endeavour is essentially about collectivising knowledge processes, it is also clear that bringing them all together in one single site of knowledge exchange would render the situation subject to existing power relations. This segmentation creates sites in which social relations will be less asymmetrical and hence less influential on the exchange of knowledge. This is thus connected to delivering the third principle of preventing unfair treatment of knowledges by assessing them against alien epistemologies. It is also connected to the first principle of not presuming vulnerability, for the assumption of vulnerability exactly enacts a correlated assumption of non-knowledgeability Dealing with this segmentation is the first requirement (and raison d'être) of knowledge brokerage here: one that is not only aimed at transporting and translating knowledge between different groups and making an impact from one to the other but also at dealing with epistemological diversity. The latter is not only about translating knowledge but also about emancipating epistemologies between groups.

Second, it is vital for knowledge brokerage that multiple definitions of the innovation problem should be enabled to circulate. In an abstract sense, this connects to the second principle of multiple future worlds (or modernities, if you like). But it also connects to the third principle of not unduly dismissing knowledge: The value of knowledge in general depends on how well it answers to the innovation problem. This means that strategically choosing one problem definition could serve the exclusion of particular knowledges as irrelevant. Demanding instead that different problem definitions are allowed, including at least one and possibly more per knowledge group, enables that such dismissal is pre-empted. This demand of multiple problem definitions adds to the tasks of the aforementioned knowledge brokerage.

The first and second recommendations for knowledge brokerage require that we be aware that knowledge relations are inextricably connected to social relations. That is to say, specific epistemic and epistemological positions are not simply occupied by persons who could select another at wish. Rather, they are connected to one's social position and are granted and validated by the community of which one happens to be a member. What is more, we must assume that these social relations are deep-rooted and internalised by all actors, including subaltern groups. This means that if we want to prevent particular epistemologies from becoming dominant, we must also abate the concurring social dominance. There is a need to enable knowledges to operate irrespective of their connected social position.

To achieve this, different modes of operation are needed, much like the front stage and back stage that Bijker, Bal, and Hendriks (2009) describe in the context of expertise in democracy. In front-stage situations, expert knowledge is confronted with alternative accounts of reality (ontologies) and alternative ways of knowing (epistemologies), and called to account publicly. Insofar as expertise has a privileged position, it will have to work hard (or depend on external power) to maintain epistemic authority. In back-stage situations, in contrast, knowledge is only held accountable to its native epistemologies. Expert knowledge is assessed primarily by the experts themselves within the confines of a profession or discipline. And in our case study, farmers' knowledge is only validated against the criteria that farmers themselves hold of good farming knowledge.

The backstage is comparably unproblematic, as indeed we managed to have talks with all parties involved in ways that allowed for their knowledge validations to be discussed. The frontstage is more complicated, though: How can we emancipate epistemologies such that they become capable of critiquing one another, thus answering to the fourth principle? That is in fact to ask: How can we install agonism in the sense meant by Mouffe in the practice of knowledge brokerage for innovation?

A fair critique of knowledges is thus to be pursued, which is only possible if the supporting legitimation and validation is supplied together with the knowledge it supports. For specific actors, especially subaltern ones, social hierarchies will make it impossible to level such criticism. This means that there is a task for knowledge brokers to do it on their behalf. This is comparably radical vis-à-vis existing notions of knowledge brokerage. The core task is usually understood as translating knowledge and adapting it to the recipients' epistemology; not to put that very epistemology in a critical perspective. In the current case study, we had no time to make this additional critical step. We did present the idea that epistemologies are limited, and it found a willing ear—also among policymakers and academics. Trying to actually challenge those epistemologies is a step further, which would be an interesting topic for further exploration and research. It is also the third recommendation for knowledge brokerage: start seeing the role of knowledge broker not only as translator and facilitator, but also as an active participant in the critiquing of knowledges.

Ultimately, the innovation process will need some form of closure: a conclusion about what the next steps should be. As exemplified here, consensus is unlikely to be

attained, and it can also be undesirable because of its potentially suppressive nature. It is therefore up to knowledge brokers, in concert with other parties involved, to draw up a best compromise. At the same time, they should be *explicit about the contingency and situatedness* of the content of the compromise. In other words, to keep explicit how it is not an eternal truth in the style modernist science would have it, but rather something constructed, social and temporal, and with a progeny in a context of power relations. Two challenges loom here. First, it will require a substantial diplomatic effort to keep the dominant parties on board, as they typically have the power to have it their way anyway. Second, it is not self-evident that the knowledge broker has the ironic privilege, as was ascribed by standpoint theorists to subordinate parties, of being able to recognise and articulate the conditions of power under which respective knowledges and their suppression come about. Worst case, it could amount to a vulgar travesty, if knowledge brokers start critiquing on behalf of subordinate parties—recall the first principle of not assuming vulnerability. But ideally, after proper preparation and training, the knowledge broker may be able to do exactly that in a way that enjoys endorsement from all parties.

Lessons for RRI in a Global South Perspective

This article has so far presented tentative lessons to be learned for knowledge brokerage in a specific case study. From various literatures and most centrally the political philosophy of Chantal Mouffe, I took the central idea that contestation is vital to emancipate oppressed voices, that this is not only about knowledges but also about their epistemologies. This amounted to four principles—assumption of resilience, non-universal modernisation, emancipate knowledges and their epistemologies in tandem, and allow all epistemologies and knowledges to critique others—and three recommendations for knowledge brokerage in practice—segment knowledges and grant each their backstage, let multiple problem definitions circulate and make critiquing part of the practice of knowledge brokerage. What remains to be discussed now is a broader perspective on what can be learned here for RRI in distinctively Global South situations, and possibly what political theory can learn from the strategic research site of innovation.

While it always runs the risk of erecting a caricature, it is vital to specify here some things that seem, from this case study, different from the West. One thing is that in India, the very thought that innovation is something heterogeneous and requires connections across the boundaries between professional and social groups is much less of an accepted fact than in Western frameworks of innovation. Rather, people tend to be concerned with their own distinct task or problem. This entails a central role for knowledge brokerage as described above. First, it needs to be broader than only making an impact from science on policy. Second, it needs to facilitate specifically the forms of contestation and critique developed here.

Another issue is that subordinate groups in the Global South are even more deprived than in the West of means to get their voice heard. This means that more

than in the West, social hierarchies and inequalities will exacerbate epistemological gaps. Also, this may in practice appear as a knowledge deficit (cf. Wynne, 1982), which may invite approaching it as such, against the lessons learned in STS. This again renders knowledge brokerage with contestation even more vital.

How does all this relate to the discourse of *RRI*? While there are many agendas going under that very name, they share an aim of making the innovation process more democratic, in many different senses: broadening the ownership of problems as well as solutions, broadening the knowledge base informing the innovation process, the expression and prioritisation of values and interests, to mention the most regularly occurring ones. Strategies are usually aimed at upstream intervention, and concepts such as responsiveness (Owen et al., 2012) and anticipation and reflexivity (Stilgoe et al., 2013) are mobilised to capture this.

To the very idea of RRI as a move of democratisation, the warning of consensus and its ensuing oppression of marginalised voices seems pertinent anyway, and even more so in a Global South context where epistemological gaps seem to play out more. Contestation-oriented knowledge brokerage seems a step in the right direction. As a corollary, this helps to open up taken-for-granted notions of modernity and progress; which is always a theme if Western concepts are translated to the Global South. This specific implementation of the 'reflexivity' that RRI calls for is thus a vital step to make.

For political theory in general, innovation is worth of attention particularly because it is a knowledge-intensive practice. This means that any emancipation achieved in innovation is likely to have a strong knowledge component, which will be very relevant for broader ideas of political emancipation: If we accept the diagnosis that unfair distribution of power correlates to unequal rights to speak for different knowledges, then emancipation may as well run through emancipation of those knowledges. The proposed practice of knowledge brokerage may play a path-breaking role there.

DECLARATION OF CONFLICTING INTERESTS

The author declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

FUNDING

This work was funded by Netherlands Organization for Scientific Research [Nederlandse Organisatie voor Wetenschappelijk Onderzoek], grant number 31399300, and DSM India.

NOTES

1. Democratisation means here: either opening up ways to exert influence or providing a convincing and acceptable justification why such influence should not be given. The latter is, for example, the case with police forces. Ordinary citizens have no direct say in how the police is organised and

operates. Yet a police force has a very clear and legitimate place in democratic systems. This realm beyond direct civic influence is not discussed in this article.

2. Dutch: brede maatschappelijke discussie.
3. 'Comparative' is not meant here as an attempt at ranking the knowledges and singling out the best ones, but in the same meaning as in 'comparative philosophy', where knowledge systems are presented vis-à-vis each other, without recourse to any overarching criterion for truth or validity.
4. The research team consisted of Wiebe E. Bijker, Annapurna Mamidipudi, Poonam Pandey, Amelie Riedesel and the author.
5. Two members of our team were native Indians (whatever that means in view of the huge cultural and political diversity within India). This helped me greatly to add nuances to my view beyond all stereotypes, but my mental model of India as 'other' was never fully eliminated.

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