



What (science for) adaptation to climate change in Colombian agriculture? A commentary on “A way forward on adaptation to climate change in Colombian agriculture: perspectives towards 2050” by J. Ramirez-Villegas, M. Salazar, A. Jarvis, C. E. Navarro-Valcines.

Article

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1 **What (science for) adaptation to climate change in Colombian agriculture? A**
2 **commentary on “A way forward on adaptation to climate change in Colombian**
3 **agriculture: perspectives towards 2050” by J. Ramirez-Villegas, M. Salazar, A.**
4 **Jarvis, C. E. Navarro-Valcines.**

5

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12 **Abstract**

13 Climate change is putting Colombian agriculture under significant stress and, if no adaptation is
14 made, the latter will be severely impacted during the next decades. Ramirez-Villegas et al. (2012)
15 set out a government-led, top-down, techno-scientific proposal for a way forward by which
16 Colombian agriculture could adapt to climate change. However, this proposal largely overlooks the
17 root causes of vulnerability of Colombian agriculture, and of smallholders in particular. I discuss
18 some of the hidden assumptions underpinning this proposal and of the arguments employed by
19 Ramirez-Villegas et al., based on existing literature on Colombian agriculture and the wider
20 scientific debate on adaptation to climate change. While technical measures may play an important
21 role in the adaptation of Colombian agriculture to climate change, I question whether the actions
22 listed in the proposal alone and specifically for smallholders, truly represent priority issues. I
23 suggest that by i) looking at vulnerability before adaptation, ii) contextualising climate change as
24 one of multiple exposures, and iii) truly putting smallholders at the centre of adaptation, i.e. to learn
25 *about* and *with* them, different and perhaps more urgent priorities for action can be identified.
26 Ultimately, I argue that what is at stake is not only a list of adaptation measures but, more
27 importantly, the scientific approach from which priorities for action are identified. In this respect, I
28 propose that transformative rather than technical fix adaptation represents a better approach for
29 Colombian agriculture and smallholders in particular, in the face of climate change.

30

31 **Keywords**

32 Vulnerability, Adaptation, Climate change, Agriculture, Smallholders, Colombia

33

34 **1 Introduction**

35 Several recent studies have shown that climate change is putting Colombian agriculture under
36 significant stress and that it is expected to do so increasingly over coming decades (e.g., Pabon
37 2003, Bradley et al. 2006, Ruiz 2010). The expected effects of climate change vary significantly
38 because of the high diversity of pedoclimatic conditions and farming systems that are typical of
39 Colombia. Nevertheless, there is agreement that overall, the potential threats to agricultural
40 production outweigh the opportunities (e.g. Zhao et al. 2005, Cline 2007, Pisco 2010) and that if no
41 adaptation is made, Colombian agriculture will be severely impacted by climate change during the
42 next decades (Ramirez-Villegas et al. 2012).

43 Agriculture is a key sector of the Colombian economy in terms of contribution to national wealth,
44 food security and employment (Pisco 2010, Ramirez-Villegas et al. 2012). Therefore, it is strategic
45 and urgent for Colombian agriculture to respond promptly to climate change. However, the
46 Colombian government has tended to prioritise other climate-related challenges, such as
47 biodiversity conservation and disaster management (Lau et al. 2011). Ramirez-Villegas et al. (2012)
48 noted that despite growing evidence about the impact of climate change in Colombia, there are still
49 serious gaps in knowledge concerning those measures that could be implemented as part of
50 national, regional and sectorial adaptation plans.

51 Against this backdrop, Ramirez-Villegas et al. (2012) set out a proposal for a way forward by which
52 Colombian agriculture could adapt to climate change. They identify, in essence, four priorities for
53 action:

- 54 1. Information production in the form of, e.g., crop- and region-based climate change impact
55 assessments, in order to select and prioritise adaptation options and information accessibility,
56 e.g., through inter-institutional, free-access databases.
- 57 2. Technological development and economic measures. Research, development, validation and
58 transfer of technologies, crop management and development of subsidies and insurance
59 schemes to support farmers.
- 60 3. Institutional restructuring and inter-institutional networks. Improved coordination among
61 institutions (e.g., ministries, governmental and non-governmental agencies responsible for
62 specific sectors, regions, or crops) to improve data availability, access to international funds
63 and the efficiency and effectiveness in spending the available funds and implementing the
64 adaptation measures.
- 65 4. Prioritisation of smallholders' adaptation. Smallholders rely on a lower level of technological
66 development and therefore, are expected to be less capable of adapting to climate change.

67 Ramirez-Villegas et al. (2012) outline what could be described as a government-led, techno-
68 scientific approach to adaptation. In this commentary, I discuss some of the hidden assumptions

69 underpinning this proposal and of the arguments employed by Ramirez-Villegas et al., based on
70 existing literature on Colombian agriculture and the wider scientific debate on adaptation to climate
71 change. While technical measures may play an important role in the adaptation of Colombian
72 agriculture to climate change, I question whether the focuses listed in the proposal alone and
73 specifically for smallholders, truly represent priority issues. I suggest the need for a reconsideration
74 of the techno-scientific approach to the challenge of climate change and discuss its implications for
75 researching climate change adaptation and vulnerability in Colombia.

76

77 **2 Technical-fix versus transformative adaptation**

78 Ramirez-Villegas et al. (2012) approach the challenge of responding to climate change through
79 informational, technological (e.g., technical support, new crop varieties, crop management) and
80 economic (e.g., subsidies, insurance schemes) measures. This is a top-down, technical-fix approach
81 (Giddings et al. 2002, Robinson 2004), which defines adaptation to climate change as a problem of
82 a technical nature, i.e., one that can be solved by intervening through technical measures (these
83 being technological or economic) to re-establish the balance between human and environmental
84 systems, which climate change threatens to disrupt, e.g., as measured in terms of crop production.
85 As noted by Giddings et al. (2002), technical solutions are attractive because they can be introduced
86 relatively quickly and they do not require fundamental reconsideration of the characteristics and
87 relationships between the human and environmental systems. The implicit aim of such an approach
88 is to maintain the functional persistence of farming systems in a changing environment, i.e., their
89 resilience (Pelling 2011).

90 By framing the effort of responding to climate change as adaptation, rather than vulnerability
91 reduction, Ramirez-Villegas et al. (2012) inevitably shift the focus from the causes of vulnerability
92 (i.e., “why” adaptation is needed) to the response to climate change (i.e., “how” to adapt) (Ribot
93 2011). As noted by Ribot (2011) and O’Brien et al. (2007), such a shift is much more than
94 semantics. It places the risk within the hazard (i.e., climate), naturalising adaptation as a natural
95 response to a stimulus and thus, drawing attention away from the social causes of vulnerability, the
96 socially differentiated risks to which populations need to adapt and from the attribution of
97 responsibility for this state of vulnerability (Pelling 2011, Ribot 2011). Not surprisingly, Ramirez-
98 Villegas et al.’s analysis largely overlooks the root causes of Colombian agriculture’s vulnerability
99 but “actions labelled adaptation should be based on deep knowledge of vulnerability” (Ribot
100 2011:1161). While exposure and sensitivity of different regions and crops to climate change are
101 detailed, no comparable level of analysis is reached with respect to why farmers and particularly
102 smallholders are considered vulnerable to climate change, except for a mention of their low
103 technological development. In fact, several studies have illustrated how under certain socio-

104 ecological conditions peasants show a high adaptive capacity to economic, social and
105 environmental stresses (Forero 2002, Forero 2003, Torres 2002, De los Rios and Almeida 2010,
106 Perez et al. 2010, Corrales 2011). As documented by these studies, adaptation does not need to take
107 a technological form but instead, can consist of socio-economic strategies (e.g., temporary
108 migration) and social rules of cooperation, reciprocity, risk sharing, labour and resource access and
109 allocation. Furthermore, the definition of vulnerability adopted by Ramirez-Villegas et al. (2012),
110 i.e., “the susceptibility of the agriculture sector to the biophysical and hence, economic impacts of
111 climate-related issues”, in contrast to the more commonly referred Intergovernmental Panel on
112 Climate Change (IPCC) definition (IPCC 2007) excludes the reference to adaptive capacity and
113 thus, justifies the small consideration given to this vulnerability component. In summary, assuming
114 that the policy goal in the face of climate change is one of maintaining the functional persistence of
115 existing farming systems through adaptation measures that are technical in nature, leaves us at best
116 with the doubt of what exactly it is that makes Colombian farmers and in particular smallholders,
117 unable to adapt to climate change and whether technical measures are the most effective way to
118 address such causes.

119 While specific studies on Colombian farmers’ vulnerability to climate change are scarce, a
120 significant body of scholarship has investigated the unresolved agrarian question that structurally
121 characterises Colombian agriculture. Among the most significant features there are: a highly
122 concentrated land distribution, precarious land rights, a static social hierarchy that hinders upward
123 social mobility, malfunctioning institutions, the lack of infrastructure and services, the presence of
124 political elites that has limited the full development of an open democratic life, land use conflicts
125 and sustainability crises (Etter and Villa 2000, Fajardo 2002, Forero 2002, Leon and Rodriguez
126 2002, Perez and Perez 2002, Sánchez 2002, Borrás 2003, Forero 2003, Forero and Ezpeleta 2007,
127 Mesias 2009, Forero 2010, Salgado 2010, UNDP 2011). Peasants and smallholders, together with
128 women, indigenous and Afro-Colombian communities, are the social categories that have suffered
129 the most from the structural crisis of Colombian agriculture, as indicated by their comparatively low
130 levels of human security (UNDP 2011). Despite their fundamental contribution to economic wealth,
131 national food security, agricultural export and to the social and cultural life of the country (Forero
132 2010, Salgado 2010), peasants and the value of peasant economies have historically lacked social,
133 economic and political recognition (Perez and Perez 2002, Sánchez 2002, Forero 2003, UNDP
134 2011). This has contributed to their marginalisation, lack of political representation and of access to
135 key resources (e.g., land, water), financial support and credit (Forero 2003, UNDP 2011), which are
136 root causes of the low technological development of smallholders.

137
138 Thus, the evidence outlined here suggests that Colombian peasants’ vulnerability is significantly

139 interconnected to the low levels of human security that characterise many rural areas in the country
140 and is deeply rooted in social and political structures, social values and institutional settings. Human
141 security is “something that is achieved when and where individuals and communities have the
142 options necessary to end, mitigate, or adapt to threats to their human, environmental, and social
143 rights; have the capacity and freedom to exercise these options; and actively participate in pursuing
144 these options” (GECHS 1999) and is known to be associated with adaptive capacity (Barnett 2003,
145 GECHS 1999). A technical-fix approach alone, such as that put forward by Ramirez-Villegas et al.
146 (2012), hardly tackles any of these structural, deeply rooted social causes of vulnerability. On the
147 contrary, it is possible to hypothesise that this very social and political configuration could
148 undermine the effect, or act as barriers to, the implementation of technical measures. For example,
149 social recognition is a prerequisite for the targeting of subsidies or insurance schemes to
150 smallholders and peasants (e.g. Forero 2010). Similarly, well-functioning institutions are a
151 prerequisite for the effective and efficient implementation of any technological or economic
152 adaptation measure (e.g. Borras 2003).

153 I suggest that adopting a transformative rather than technical-fix approach to adaptation would help
154 to prioritise the measures that tackle the deep, structural causes of limited adaptive capacity and
155 high vulnerability, rather than end-point, palliative technical measures. The concept of
156 transformational adaptation has been increasingly used in literature on climate change adaptation,
157 although with different interpretations (O’Brien 2011, Pelling, 2011, Ribot 2011). It helps to
158 understand adaptation as a process of social-ecological change rather than a spot technical
159 intervention. Transformation entails a radical (rather than incremental) change, i.e., one that
160 involves the core elements or defining system characteristics (e.g., function, structure). Therefore, a
161 transformation is configured as a change *of*, rather than *in* a system. A transformed system would be
162 one that has modified its core elements, such as values, worldviews, economic, political and
163 institutional configurations and is not only able to respond or adapt to climate change but is able to
164 redirect its development pathway to eliminate the root causes of vulnerability (Pelling 2011). Thus,
165 the policy goal for transformational adaptation is not the maintenance of a system but the
166 reconfiguration of the structures of development, achieved through a radical change of the
167 overarching political and economic regime and social structures (Pelling 2011).

168 In effect, the calls for transformative rural policies trace back in Colombia at least six decades to the
169 milestone work of Orlando Fals-Borda among peasants in the Colombian Andes (Fals-Borda 1955).
170 More recently, the United Nations Development Programme (UNDP) (UNDP 2011) outlined a
171 “transformative rural reform” built around the pillars of poverty reduction, the end of rural conflict,
172 human security, land access and institutional and human development. Together with other recent
173 insightful analyses of Colombian rural and peasant communities (e.g., Forero 2003), this UNDP

174 report could represent a basis for a debate around the principles and priorities of a different way
175 forward in vulnerability reduction and increased adaptive capacity of Colombian smallholders in the
176 face of climate change.

177

178 **3 Contextualising agricultural adaptation to climate change in Colombia**

179 Ramirez-Villegas et al. (2012) discuss agricultural adaptation to climate change in Colombia in
180 isolation from its wider social, economic and political context. The adoption of this particular
181 perspective inevitably leads to the proposal of sectorial measures and to the identification of
182 sectorial-related organisations and institutions as key stakeholders for adaptation development and
183 implementation.

184 However, it is widely acknowledged that climate change often corresponds with other phenomena
185 to pose a potential threat to local rural communities (“double (or multiple) exposure”) (O’Brien and
186 Leichenko 2000). Farmers need to respond, not only to climate change but also to other socio-
187 ecological phenomena, whereby there might be synergies, or trade-offs between the actions taken in
188 response to the different simultaneous pressures. One such phenomenon is that of globalisation,
189 whereby farmers need to adapt to the combined pressures of climate change and international
190 markets simultaneously. The free trade agreement (Tratado de Libre Comercio - TLC) between
191 Colombia and the United States of America that recently came into effect configures an almost
192 prototypical situation of double exposure for Colombian farmers, big producers and smallholders
193 alike. Although precise estimates on the TLC’s effects on Colombian agriculture are yet to be
194 produced (Torres 2010), it is clear that the challenges for the sector are potentially very significant,
195 especially for some products (e.g., poultry and pork meat, beans and several cereals) that are
196 exposed to competition from USA producers (Garay et al. 2010). It is apparent that such a
197 substantial change of the Colombian agricultural market needs to be factored in when discussing
198 climate change adaptation. The economic performance of agricultural units in the national and
199 international markets will largely determine the level of resources that the sector will be able to
200 invest in order to sustain the costs of climate change adaptation. In addition, the TLC sets
201 institutional and normative structures that appear inconsistent with some of the economic measures
202 proposed by Ramirez-Villegas et al. (2012). In particular, the TLC requires the progressive
203 cancellation of tariffs and support schemes to Colombian agricultural producers (Garay et al. 2010),
204 which at best reduces the scope for the use of subsidies as climate change adaptation measures.
205 Therefore, the relevance of the TLC for adaptation to climate change in Colombia is double: as a
206 determinant of adaptive capacity (i.e., financial resources to respond to climate change effects) on
207 the one hand and on the other, as a constraint to the development and implementation of specific
208 technical adaptation measures.

209 A second highly important contextual factor that is not considered in Ramirez-Villegas et al.'s
210 (2012) analysis is violent conflict. Decades of pervasive and persistent violent conflict has not only
211 claimed its toll of human lives, including those of farmers but resulted in the forced displacement of
212 hundreds of thousands of households, the disruption of rural communities' social fabric and
213 deprivation of access to land and rights to its use and thus, contributing to rural poverty (UNDP
214 2003, Comisión 2009, Ganzáles 2009, Forero 2010, UNDP 2011). Together with the legacy of
215 distrust that the conflict has left in many areas, the disruption of rural communities is a central cause
216 of the decline in social capital, a key component of adaptive capacity (Adger 2003) and of the low
217 level of farmer organisation observed in Colombia compared with other Latin American countries.
218 Often, in violation of the most basic human rights, violent conflict has also favoured land
219 accumulation, reinforced social inequalities and contributed to institutional inefficiency and
220 ineffectiveness in providing basic services to rural communities (Perez and Perez 2002, UNDP
221 2011). Smallholders and peasant are among those who suffer most from violent conflict (Comisión
222 2009, Forero 2010, UNDP 2003, 2011). Therefore, as for the TLC, the relevance of violent conflict
223 for adaptation to climate change in Colombia can be interpreted from a double perspective. Firstly,
224 it contributes to and exacerbates the sources of vulnerability already mentioned with respect to the
225 agrarian crisis. Secondly, it acts as a constraint to the development and implementation of specific
226 technical adaptation measures. For example, response strategies in the context of conflict and
227 insecurity are usually short-term (i.e., coping) rather than long-term (i.e., adaptation). Planning and
228 forward thinking, which are prerequisites for the perception of long-term climate change risks and
229 for the implementation of adaptation measures, are hardly possible in the context of poverty,
230 conflict, insecurity and emergency (Banerjee and Duflo 2011).

231 In summary, framing agricultural adaptation in Colombia in its historical, social, political and
232 economic context helps uncover a wider set of multiple exposures and therefore, to reconsider the
233 prioritisation of adaptation measures in Colombian agriculture in the face of trade-offs and
234 constraints. For example, do the technologies and new management practices proposed to confront
235 climate change also help compete in liberalised markets, or there are trade-offs between adaptation
236 to climate change and to the TLC? Importantly, it also suggests that agricultural adaptation to
237 climate change should not be the exclusive responsibility of agriculture or environmental related
238 organisations (ministries, agencies, extension services, agricultural research institutions) but
239 requires the cooperation and coordination of a much broader set of institutional and non-
240 institutional political, social and economic actors.

241 242 **4 The role of farmers in adaptation to climate change in Colombia**

243 Ramirez-Villegas et al.'s (2012) proposal foresees a marginal role for farmers in adaptation to

244 climate change. It does not exclude the involvement of stakeholders and farmers in the formulation
245 of adaptation projects, e.g., in workshops “to elicit feedback regarding strategies and conclusions”
246 but considers farmers mostly as “recipients” of adaptation in a technology development and transfer
247 process, which is led by expert knowledge and structures (i.e., agencies, agricultural research
248 centres and extension services).

249 In so doing, Ramirez-Villegas et al. (2012) implicitly adopt a prescriptive decision model that
250 presumes, rather than tries to understand farmers’ adaptive actions (Risbey et al. 1999, Krandikar
251 and Risbey 2000) and farmers are expected to respond in an economically rational way, i.e., to
252 adopt the technical solutions proposed by experts. However, there is abundant evidence in the
253 literature that farmers do not necessarily behave like rational economic actors (e.g., Krandikar and
254 Risbey 2000, Feola and Binder 2010). Therefore, effective policies need to be based on a sound
255 understanding of farmers’ actions, which includes the way rational expectations, values, social
256 norms, feelings, habits and contextual factors produce and reproduce actions that are adaptive to the
257 social, as well as to the natural environment, as perceived by the farmer (Feola and Binder 2010).
258 Therefore, to understand farmers’ adaptive, or mal-adaptive, farming practices requires the
259 understanding of “the decision-making processes into which adaptations to climate change can be
260 integrated” (Smit and Wandel 2006:285). This approach differs from the socio-economic
261 assessment of the type proposed by Ramirez-Villegas et al. (2012), in that its “aim is not to score
262 adaptations or measure relative vulnerabilities, or to quantify impacts or estimate effects of assumed
263 adaptations. Rather, the focus is to document the ways in which the system or community
264 experiences changing conditions and the processes of decision-making in this system (or that
265 influence the system) that may accommodate adaptations or provide means of improving adaptive
266 capacity” (Smit and Wandel 2006:285).

267 Furthermore, the lack of consideration of the farmers risks contributing to the imposition of
268 adaptation measures rather than their co-development and thus, creating the basis for policy failure
269 and most importantly, reproducing the lack of recognition that is at the root of Colombian peasants’
270 vulnerability. Research has shown that farmers’ and technical experts’ visions can differ and that
271 this gap can result in policy failure, when policies do not address the needs identified by the target
272 communities themselves and are not based on a solid understanding of the social context in which
273 they are implemented (e.g., Schoell and Binder 2009a, 2009b). Bottom-up, participatory approaches
274 have been shown to be a fruitful way to overcome such barriers in agricultural development. There
275 are many examples of successful participation in Colombia and in Latin America from which
276 lessons for agricultural adaptation could be learned (e.g., Braun and Hoddé 2000, Perry 2004). They
277 can be led by farmers, integrative of novel technologies with ancient wisdom and experiential
278 knowledge and able to consider systemically social as well as environmental dynamics, instead of

279 separating them (Pretty 1995, WI 2011). In contrast to the technology transfer proposed by
280 Ramirez-Villegas et al. (2012), the aim is to empower farmers to identify vulnerabilities, formulate
281 and pursue responses and to share the risks and responsibilities of adaptation. Indeed, the “essential
282 factor in strengthening farmer innovation capacity is not technology per se but rather the
283 construction of social processes that support experimentation and learning” (Braun and Hocké
284 2000:51). Therefore, bottom-up participatory processes are arenas for social learning in which not
285 only, e.g., new technologies or management practices are introduced but where a change in
286 understanding occurs through social interactions within social units or communities of practice
287 (Pretty 1995, Braun and Hocké 2000, Reed et al. 2010).

288 In summary, uncovering the causes of vulnerability entails learning *about* farmers’ actions and
289 practices and *with* farmers in trans-disciplinary processes of knowledge co-production. The latter
290 are no silver bullet and by no means an easy or short path to take. To scale-up local, small-scale
291 participation processes might prove to be a further challenge. However, the process by which
292 adaptation measures are developed matters. A top-down, techno-scientific approach contributes to
293 reproducing and reinforcing the lack of social recognition and voice that is among the root causes of
294 Colombian peasants’ low adaptive capacity and vulnerability. A bottom-up participatory approach
295 would not only constitute a first essential step towards a better understanding of vulnerability but
296 also, would in itself tackle those vulnerability factors and thus, directly play a transformative role.

297

298 **5 Conclusions: what (science for) adaptation to climate change in Colombian agriculture?**

299 I have questioned Ramirez-Villegas et al.’s (2012) priorities for action and proposed an alternative
300 perspective on Colombian agriculture in the face of climate change. Given the pace and scale of
301 climate change and the state of vulnerability, in particular of smallholders in Colombia, Ramirez-
302 Villegas et al.’s (2012) call for action and the importance of the adaptation measures proposed can
303 be appreciated. Information, technologies, crop management practices and economic schemes are
304 options that can significantly contribute and are indeed possibly necessary, to respond to the
305 challenges of climate change and mitigate its negative effects on rural livelihoods. Similarly, an
306 institutional reorganisation and a national adaptation plan to manage better the unprecedented
307 challenges of climate change can be expected to contribute positively to a coordinated and efficient
308 response. Nevertheless, there are reasons to believe that Colombian smallholders’ vulnerability does
309 not ultimately depend on their level of technological development but more fundamentally on low
310 levels of human security, which are intertwined with deeply rooted social, political and economic
311 processes, systems of value, and formal and informal institutional settings. I suggest that tackling
312 such root causes of vulnerability forces the reconsideration of the priorities for action against
313 climate change and that, if such root causes of vulnerability are not tackled, any technical

314 adaptation measure might just be palliative. In other words, tackling the root causes of vulnerability
315 means to tackle those sources of vulnerability that are ultimately hindering farmers' adaptive
316 capacity and, at the same time, to pave the way for more specific, technical measures that might
317 further advance adaptation in the face of climate change.

318 The scale of the climate change challenge calls for novel, alternative and complementary
319 approaches to inform much needed action towards vulnerability reduction and increased adaptive
320 capacity.

321 Ultimately, what is at stake is not only the list of priorities of adaptation measures but also the
322 scientific approach to adaptation of Colombian agriculture from which priorities for action are
323 identified. In this respect, I have argued that transformative adaptation rather than a technical fix
324 might represent a better approach for Colombian agriculture and smallholders in particular, in the
325 face of climate change. Transformative adaptation focuses on vulnerability rather than on
326 adaptation, takes a more holistic perspective (e.g., human security) rather than a technical one and
327 does not aim to maintain existing and possibly non-desirable, agricultural systems but rather to
328 radically change them in order to eliminate the root causes of vulnerability. Moreover, I have
329 stressed the importance of contextualising climate change as one of many pressures on Colombian
330 agriculture. This helps uncover the constraints, trade-offs, or synergies, that may exist between
331 actions in response to different but simultaneous pressures and to broaden the spectrum of actors
332 that possibly need to be involved in order to enhance farmer's adaptive capacity. To contextualise
333 climate change also means to acknowledge, and to avoid, that technical adaptation to climate
334 change in agriculture can have the negative side-effect of increasing vulnerability to other stresses
335 (e.g. the TLC). Finally, I have argued for a more central role of farmers in the definition of
336 vulnerability analysis and development of adaptation options. This can involve both learning *about*
337 farmers (i.e., to understand their mal-adaptation decisions) and *with* them, in participatory, social
338 learning process in which science engages with other forms of lay knowledge and in doing so, takes
339 directly a transformative role in society.

340

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346

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