RC1

Dear authors, I very much appreciate the improvements of the manuscript and think it is ready to be published. I appreciate the provision of an ODD+D. I have only checked the first equation in the ODD+D in section 3.4.1: SEUT_no_action and realized that in the ms the authors have the coefficient beta and p depending on the agent x and in the ODD+D description this has not been done. Thus, I would encourage the authors to carefully double check that everything is consistent. Apart from that I guess this article is ready to be published and hopefully will be discussed in the scientific literature.

Thank you for your extensive first comments and for providing your second comment. We changed the equations in 3.4.1 in the ODD+D to match to those in section 2.3 of the manuscript. Furthermore, we went through both the ODD+D and the manuscript for last checks and ensured that all are consistent.

RC2

Thank you to the manuscript authors for their thorough and detailed response to my initial review comments. I find the manuscript to be improved with their revisions. I also acknowledge the complexity of the modeling effort at hand, and appreciate that the authors have added material to the text acknowledging this complexity, and making clear where the analysis is necessarily limited in scope.

My primary remaining comment is that I found the authors response regarding model assessment/validation to be rather thin. To assess the performance of the model, the authors primarily compare model results to large-scale patterns of groundwater development/exploitation/depletion that is described in Roy and Shah (2002), and indicate that model results replicate this general pattern. While I am not intimately familiar with Roy and Shah (2002), upon my brief examination it seems to argue that groundwater use is largely driven by demand-side factors (e.g., demands for crops) and does not present a strong argument that increased groundwater exploitation is due to drought our lack of surface water availability (it seems to in fact argue against this in many instances). While the patterns of groundwater development/exploitation/depletion may nonetheless be similar (I'd imagine this could be replicated even without any drought response mechanism in place in the model), this inconsistency is rather conspicuous and weakens the assessment/validation of model performance using Roy and Shah.

As the model design is premised on groundwater adoption/use as a surface water drought-response mechanism, I think that identifying evidence that specifically bolsters the specific connection between groundwater development and drought response would be much more relevant to assess whether model dynamics are indeed representative of *reality. At the very least, I think the use of Roy and Shah to corroborate model results and dynamics should be clarified*.

Thank you for the comment. Indeed, the patterns described by Roy and Shah could likely be replicated without incorporating the drought response mechanism. Studies focused solely on well deepening, such as those by Sayre & Taraz (2019) and Robert et al. (2018), have successfully replicated this specific mechanism. However, these studies—aside from being limited to a single well in a one-dimensional scenario—are less accurate because they omit critical drought mechanisms that our study incorporates. Below we identify the four key ways in which droughts influence farmers' adaptation dynamics in our model, and show that these processes match with literature.

Our modelling results show that:

1. Drought response boost the uptake of wells through increased risk perception. This initial well uptake then boosts short-term (water/drought) resilience. However, our results and sensitivity analysis also show that economic factors (i.e. interest rates and well cost) are most important for well uptake, as risk perception is higher for subsequent droughts, but is unable to boost well uptake due to higher well costs and indebtedness;

2. Droughts lead to overextraction from boreholes to compensate for the lack of rainfall, which results in the accelerated decline of groundwater depth and wet wells;

3. Droughts result in the switching to more water-resistant crops for farmers without irrigation access;

4. Droughts result in failed harvest and indebtedness through having to compensate crop losses with micro-credit / loans and needing to pay outstanding loans for dry wells.

This is consistent with the following literature results.

1. Shah (2009) reports that "*groundwater wells have been the principal weapon Indian farmers have used to cope with droughts*" and that "*this is evident in the fact that well digging has tended to peak during years of droughts*". It can also be seen in figure 4.1 of Pahuja et al. (2010), where we see increases the usage of groundwater sources during/after dry periods. From studies in other regions we know that varying, e.g., risk perception is a way to capture such behavior (Aerts et al., 2018; Kunreuther et al., 1985; Schrieks et al., 2021; Tierolf et al., 2023). Furthermore, Solomon & Rao (2018) report, for example, that "*groundwater usage in semi-arid regions has increased the short-term resilience of communities in the region .. however, the exploitation of the resource for irrigation has resulted in critical groundwater levels*" and that "... *monsoonal irregularity along with increasing instances of drought has prompted farmers to adapt by shifting from supplemental to complete groundwater irrigation*", and Udmale et al. (2015) report that *"The extent of irrigation played a key role in mitigating drought damage to crops ... shows the importance of bringing more crop areas under irrigation to increase farmers'* *adaptive capacity to drought.".* However, we acknowledge that drought (risk perception) is not always the primary factor for farmers driving well adoption. Instead, demand-side considerations or cultural influences (Solomon & Rao, 2018) can play a more significant role.

2. "*groundwater-irrigated area in Jaipur actually declined by over 10 percent between 2001 and 2006 due to groundwater overdraft and drought in the 2005–2006 cropping season*" (Birkenholtz, 2014), "*Groundwater extraction is increasing every year, except for a partial (but temporary) recovery following years of exceptionally heavy monsoon rainfall. Excessive pumping of groundwater to cope with drought impacts has led to groundwater depletion, which is an important concern of Maharashtra State*." (Udmale et al., 2014), "*In water-scarce years, farmers and utilities resort to groundwater to compensate for inadequate rainfall and surface water supplies.*" (Pahuja et al., 2010).

3. Many studies report that farmers change to low water consuming crops as drought adaptation (Fishman et al., 2017; Udmale et al., 2014) and, e.g., switch back to traditional drought-tolerant crop varieties after wells have gone dry (Birkenholtz, 2009).

4. Similarly, taking out loans after drought loss and difficulties repaying loans after droughts is often observed (Solomon & Rao, 2018; Udmale et al., 2014, 2015).

Furthermore, the overall sequence around wells, crop choices, debts and droughts that we observed, namely: groundwater well irrigation expansion, initial higher resilience, a shift to high-value water-intensive crops, rapid groundwater depletion due to overdraft and drought, farmer failures, rising indebtedness, agricultural decline and a subsequent return to non-commercial crops has been documented (that explicitly mention the role of droughts) by studies beyond those of Roy and Shah (Birkenholtz, 2014; Pahuja et al., 2010; Solomon & Rao, 2018).

We have changed the manuscript in the following ways:

1. In the introduction where we explain our choices to implement the SEUT we have added references to Shah (2009), Pahuja et al. (2010), (Solomon & Rao, 2018) and (Udmale et al., 2014, 2015) (lines 76-83) and in the discussion where we compare the pattern of well uptake and the sensitivity analysis results to literature: "*However, although we anticipated that changes in risk perception would have a stronger impact on well uptake, our results show that economic considerations were predominantly the driving factor. This aligns with other studies which mention drought response as a major driver of well uptake (Pahuja et al., 2010; Shah, 2009), but call social and economic aspirations as the main driver (Solomon & Rao, 2018).*" (lines 543-546).

2. In the discussion where we emphasize the effect more (lines 506-507). Furthermore, we compare this effect to observations and to previous modelling studies which only focused on demand-side factors and failed to capture this effect: *"Furthermore, it* *provides a much better representation of the accelerated groundwater decline during droughts observed in the field (Birkenholtz, 2014; Pahuja et al., 2010; Udmale et al., 2014), which was not captured in previous well modeling studies (Robert et al., 2018; Sayre & Taraz, 2019)."* (lines 539-542).

3. In lines 481-482 we mention that farmers with less resources or no wells switch to more drought resistant crops; In lines 542-543 we mention that: "*our results reflect a similar pattern of crop choice observed in the field, where farmers facing water scarcity during and after droughts switch to drought-tolerant crops (T. Birkenholtz, 2009; Udmale et al., 2014)."*

4. We added references to line 508 and 538 about continued loan payments / indebtedness.

Lastly, we added the well sequence as described above with references in lines 536-539.

We agree that only using Roy & Shah (2002) was inadequate and looked critically at our own results again. We hope that the changes are sufficient. Thank you for once again having a critical yet constructive view on this research.

As I mentioned above, I realize that the development, description, and application of a model of such complexity is necessarily limited, especially when confined to a single manuscript, and I appreciate the lengths to which authors have already gone in this work. I believe that the work is deserving of publication, but the assessment/validation attempts should be strengthened or at the very least clarified/qualified such as to improve the description and impact of the work.

Thank you for your understanding of the work involved in such a complex model. We are thankful for your feedback and hope you deem the manuscript sufficiently improved for publication.

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