Supplementary material to: Williams et al. (2022), 'Integrating Equity Considerations into Agent-Based Modeling: A Conceptual Framework and Practical Guidance', *Journal of Artificial Societies and Social Simulation* 25 (3), 1: [DOI: 10.18564/jasss.4816]

Appendix 1: Example Positionality and Bias Documents

Although the document is intended primarily as a tool for internal use and ongoing reflection throughout the modeling project, a version of the document could be included as a supplement to a published research article. This appendix provides several example reflections from the authors of this article, demonstrating the different forms that the document could take (e.g., first/third person, differing levels of formality).

Given that the authors of this article are based in the Global North but often work in development contexts in the Global South, issues such as colonialism appear particularly prominently in these reflections as a form of historical inequity. In other research contexts, distinct themes will likely be relevant. These documents are also based on our own growing but limited experience and, as such, are not intended as model solutions.

Example 1

These reflections relate to the ABM research in Williams et al. (2021), which examines strategies for overcoming the negative effects of large-scale land acquisitions (LSLAs) on Ethiopian smallholder farmers' food security. We admit that these reflections were made after the modeling work had already been completed and so do not agree with our recommendations for reflection to be ongoing throughout the modeling project. This is because the ideas for this paper were developed after this particular modeling work. However, we believe that post-hoc reflection is better than no reflection, as it helps to better contextualize research results.

Theme	**Reflections**
1. Positionality	● The principal researcher identifies as a White male of European descent. He is a Ph.D. student within an engineering department at a research institute in the United States. The other members of the research team identify with a range of identities. All identify as male and work at predominantly White academic institutions in the United States. Two of the research team identify as European American and one identifies as a Marwari Bihari out of place. ● Although the entire team played a role in shaping the direction of the research, the following reflection is from the perspective of the principal researcher. ● Conditioned by his academic training, the principal researcher has a primarily positivist epistemology but seeks to integrate critical theory to acknowledge the subjectivity in how people perceive reality. ● The principal researcher has never personally experienced food insecurity or lived in poverty and so lacks understanding of the lived experiences of Ethiopian smallholder farmers. Thus, he approaches the research context from an inherently outsider's perspective. ● Through its focus on LSLAs, this research attempts to mitigate the negative effects of global power imbalances between Western and non-Western countries. However, because the research team are outsiders to the modeled context, they need to remain cognizant of the risk of repeating colonialist practices through their research, such as information extraction and cultural appropriation.
2. Framing	● The framing of the research contends that the livelihoods of smallholder farmers in Ethiopia (and elsewhere) are threatened by the effects of LSLAs. Further, it contends that this vulnerability is problematic—i.e., that it *should be* reduced. ● Through its focus on contract farming as an alternative implementation of LSLAs, the research contends that this vulnerability could (and thereby should) be reduced through top-down external intervention. Contract farming is another way to integrate smallholder farmers with global commodity markets and so exists within the same worldview as LSLAs.

	• This research did not co-develop scenarios with local farmers or decision-makers. For these reasons, these solutions may perpetuate recognitional and/or procedural inequities as they may not necessarily align with community priorities. • Farmers (the agents) are modeled as heterogeneous with respect to their land endowment and family size, but we do not represent heterogeneous ethnocultural groups, gender, or other dimensions of identity. These simplifications may miss or underestimate the vulnerability of some population groups (e.g., the effects of LSLAs on women). • Due to the region-level focus of the LSLA and contract farming scenarios, the problem's framing places the onus for adaptation on the government or businesses. We do not explicitly model these actors, the political processes for implementing the strategies, or the politics of unequal access to the strategies. • The main model output is a measure of food insecurity. Because the most vulnerable households are food insecure, our model outputs are most sensitive to the experiences of these households and we therefore assume a needs- or vulnerability-based perspective on equity. • The model is predicated on the notion that smallholder food security is driven by household livelihood opportunities. Other conceptual models for food insecurity exist, which emphasize different drivers and food security dimensions that are not considered in the modeling (e.g., dietary diversity or food sovereignty). Adopting a different conceptual framework may have led to different conclusions about the ability for contract farming to improve food security.
3. Inputs	• The model's input data were drawn from household surveys conducted at four regions affected by LSLAs in Ethiopia. This survey was administered to one person in each household (the household head). These data therefore may miss important facets of food security (e.g., intra-household or gender differentials in food access) or agricultural production (e.g., vegetable gardens that are typically managed by female household members who might not have been surveyed). • The survey was administered to a subset of the population surrounding each LSLA and is not guaranteed to be fully statistically representative. In particular, because the surveys were conducted after the LSLAs, they do not provide data on households that may have been evicted from the regions. • The research team experienced some cultural clashes while collecting the surveys. This was because we had used satellite imagery to identify potential household locations. Some locals reacted very negatively to this and were worried that our research team was spying on them. Our initial approach was clearly problematic, and when designing any future surveys we will endeavor to be more culturally sensitive.
4. Quantification	• Food insecurity is a subjective measure and households likely have different perceptions around what it means to "experience a food shortage" (in the language of the survey). For example, households may compare their experience to others in their networks and therefore the empirical survey measure is likely geographically biased. In particular, it may under-represent food insecurity in vulnerable regions. Further, our model-based representation of food consumption is also imperfect; we model production and consumption of a single cereal crop and develop a threshold of food consumption below which a household is considered food insecure. Thus, there may be a mismatch between the theoretical understanding of food insecurity and our operationalization of it. • There are several potentially important processes not included within the model. First, the model does not include forest-based livelihoods, which are particularly important for land-poor and resource-constrained households. Second, we do not model social networks or sharing of resources (e.g., food) between households. Third, we do not model other social support systems, such as the productive safety net program in Ethiopia. Fourth, we do not model land degradation, which may affect crop yields and thereby the relative prevalence of food insecurity over time. These mechanisms have potentially divergent implications for equity and so it is difficult to speculate about their net effect on food insecurity. • More generally, we did not involve Ethiopian stakeholders during model development. This likely limits the model's acceptability in the modeled context and does not ameliorate power imbalances between the researchers (i.e., scientists in the Global North) and the research subjects (smallholder farmers in Ethiopia).
5. Interpretation	• We used a pattern-oriented modeling procedure to calibrate the model to the empirical data. The patterns we used were the distributions of livelihood characteristics (e.g., crop yield) across

	the agent population. Because these patterns were not binary, deciding that a model had an appropriate level of fit to the data was very subjective. Further, this process may have excluded households at the tail ends of the distributions (e.g., the very vulnerable) ● With respect to the focus on LSLAs, the principal researcher entered the modeling project with the understanding that LSLAs are generally detrimental to local livelihoods. This was the motivation for the modeling project. The modeler was likely influenced by this worldview in multiple ways throughout the modeling project. ● The principal modeler interpreted the model outputs in consultation with the rest of the research team. The model outputs were not discussed with or directly communicated to local Ethiopian communities or decision-makers. This research project was therefore relatively inequitable with respect to procedural justice as it did not actively seek to empower the communities in the target system. ● However, the main interpretation of our results was that increasing farmers' agency to respond to LSLAs could lead to more equitable outcomes. Thus, our interpretation was empowering for such communities, despite not involving them directly in the dissemination as the model outputs were targeted for a more academic audience. ● We were careful to not make any declarative statements that these results should be used to inform policies in Ethiopia (or elsewhere), and instead used the model as a tool to demonstrate this idea for further exploration in empirical research.

Example 2

These reflections relate to the ABM research in Steger (2020). The model was built to facilitate participatory rural land use planning regarding the management of a community conservation area in the Ethiopian highlands. The model purpose was to enable people involved in managing the area to explore the individual and combined effects and trade-offs of social and ecological factors controlling the spread of native shrubs in Afroalpine grassland.

Theme	**Reflections**
1. Positionality	● I am a white, cisgender American woman working primarily with an older, white American man in the coding of this model. While we are both interdisciplinary social-ecological scientists, I lean more towards critical social science theories/philosophy, while he leans more toward natural sciences and computer/data science. ● I try to do research that contributes to a more sustainable and equitable world. I was raised devoutly Catholic, and while I am no longer religious I still try to focus my work on service to others. Thus far, this has brought me to sub-Saharan Africa for my Peace Corps service (Senegal), my Master's research (Kenya), and to Ethiopia for my dissertation work. My interest in modeling is largely in its utility to people who manage environmental resources, which makes the tedium of ABM parameterization challenging for me! ● I am firmly an outsider in the area of Ethiopia where I work. I do not even speak Amharic. My stake in the management of the area is not tied to my livelihood and therefore I experience less urgency around this issue compared to the local people.
2. Framing	● The challenge is to manage shrub encroachment in an Afro-alpine grassland. The narratives surrounding the issue revolve around potential loss of the culturally and economically valuable guassa grasses. ● Local farmers have hereditary rights to protect and use the guassa grasses. There are national conservation interests as well, represented by a regional conservation office staffed by three local men with some formal conservation and tourism management education. Scientists, both foreign and domestic, are interested in the protected area largely for the endangered and endemic species that live there. Foreign documentary film-makers are also invested in the area for wildlife filming. ● We have questions regarding how much grass local people can sustainably harvest and whether or not management actions like livestock grazing or fire should be used to control the shrubs.

	The local farmers want a clear number on the amount of grass they can harvest, which is difficult given the uncertainty of the model. Scientists instead wanted to have an on-going conversation about potential future scenarios to help prepare for unexpected changes to the vegetation composition. Local people were less interested in this qualitative outcome, though local conservation officers found it helpful to think about the future in 15-30 year timescales rather than their usual five. ● Very little is known ecologically about shrub encroachment in tropical montane systems, and much debate over the relative importance of precipitation, atmospheric CO_2, grazing, and other forces on the process. Therefore, there is high uncertainty in the model parameterization, which makes me very hesitant to suggest specific harvest limits based on our modeling activities.
3. Inputs	● Certain people living around the protected area have hereditary rights to harvest grass, while others do not. We only worked with those people who claim that right, which potentially biases our understanding of the system. For example, perhaps the marginalized groups might say they are not harvesting illegally, while the management groups blame them for most of the illegal harvesting activity. ● The scientists are making all the assumptions regarding the ecological components of the model (i.e., rate of grass growth, seed dispersal, etc) and it is primarily based on secondary data from other systems as there are limited data available for this specific area. Local people helped estimate the amount of grass harvested and the frequency of harvests, but it was difficult to scale up across the large study area.
4. Quantification	● Grazing and controlled burns are management actions that are known to help curb shrub encroachment in other grasslands. However, these were not considered feasible in this area by local people. Grazing in the area has long been a subject of intense debate and violence, and they did not want to present it as an option as they are only recently feeling that people are accepting the grazing ban. There is widespread fear of fires, which are highly destructive of local property and have never been used as a management tool in the area. Therefore, we did not include either grazing or fires as management actions in the model. Some scientists involved in the project wanted to include them anyway, to illustrate the potential future options, but local people reacted very negatively to this proposal and so I made the decision not to include them. This was partially out of respect for local people's agency in the model design and application, and also to help build trust between scientists and local people so that there was less fear we would contribute to government takeover of the conservation area. There is the possibility of exploring these options in future versions of the model. ● We also did not include the so-called "illegal harvests" that occur between periods when the area is open to harvest (it is only open every 2-7 years). This is likely a significant impact, though managers did not like to discuss it as they say it is mostly under control. There is a threat that the government will take over if they do not manage the area well, so they did not want to focus on these kinds of issues. ● The decision not to include these processes contributed to our inability to give specific answers to the question of harvest limits, which was frustrating for local people who very seriously want to stop the shrubs from taking over their valued grasslands.
5. Interpretation	● As stated in the data section, we only talked to people with hereditary rights to the area. There are thousands of "illegal" users who might tell us a different story, or who might prefer different outcomes/management solutions. ● I interpreted the model outputs with some input from my American colleague mentioned above. ● A workshop was planned for August 2020 to disseminate the results of the model to local communities. This was cancelled due to COVID-19, and continues to be delayed. We are now attempting to bring an Ethiopian scientist to the US to train them in the model so that they can conduct the communication workshop at a later date.

Example 3

These reflections relate to an ABM in the early stages of development as part of a multidisciplinary Innovations at the Nexus of Food-Energy-Water Systems (INFEWS) project. The primary aim of the model is to investigate potential outcomes of heterogeneous decision-making

processes of irrigation adoption among farmers in Alabama, USA. A secondary purpose is to identify barriers to irrigation adoption among segments of the farmer population, many of which are socially and historically disadvantaged farmers.

Theme	Reflections
1. Positionality	● The principal modeler identifies himself as a White, cisgender male of mixed European-American descent. He is a faculty member in a geography department at a university in the United States. Other faculty members of the research team are males from Middle Eastern, Russian, and European-American descents from engineering and agricultural economics departments. The principal research assistant identifies as a Brown, cisgender, straight, non-disabled female of Asian-Indian descent. She is a Ph.D. student within the department of geography at an academic institute in the United States. The following reflection is from the perspectives of the principal researcher and research assistant only. ● The principal research assistant, who comes from a developing country, conditioned by her educational background, limited academic/research training, and research interests, assumed primarily an interpretive paradigm. However, having conducted research in the United States for the last three years, she not only acknowledges her confined research paradigm all this time, but is now more inclined towards maintaining a pragmatic paradigm in her upcoming projects and conducting research that benefits people. ● The principal modeler comes to this work as an outsider in terms of originating from outside the study region and a different socioeconomic and racial background than at least a portion of the study population. Because of this dislocation, the principal modeler lacks prior experience with or knowledge of the socio-cultural context in which the study takes place. Although the principal modeler grew up outside the study region, he has family there who were farmers and has studied agriculture and rural communities from various parts of the world since the start of his research career. The research assistant, an international student from a developing country, approached the research context from an inherently outsider's perspective. She wasn't familiar with the rural sociological aspects of this country, so lacks the understanding of the lived experiences and the various different challenges faced by rural communities, especially with respect to agriculture, within the US. ● The principal modeler is aware of deep socioeconomic, cultural, and racial divisions within the study area that have both historical and contemporary roots. The population of farmers in the region is highly diverse, ranging from large-scale commodity producers (mostly White) to small-scale, quasi-subsistence (mostly Black) producers. The poorest farmers face barriers at multiple levels, characteristic of multi-level poverty traps, to improving their livelihoods and well-being. ● The research assistant feels that this modeling exercise may risk repeating some of the institutional and historical research practices, such as either over-researching and exploiting certain sections of a society, which in turns make this entire research process for them intrusive and extractive, producing limited social benefit for those communities and people being researched, or excluding/neglecting underrepresented and/or minority communities.
2. Framing	● The framing of the research contends that the livelihoods of farmers are vulnerable to the effects of climate as increased climate variability today is exacerbating drought risks, which further challenges the resilience of agricultural communities globally. Further, it contends that this vulnerability to climate change should be reduced through encouragement of appropriate adaptation strategies. ● Broadly, the research asserts the need for building societal resilience towards changing climatic risks through adaptive strategies, particularly through the adoption of irrigation by farmers. Further, the study will provide a holistic understanding of cognition and behavior regarding technology adoption in response to climate change, which will be useful in informing overall water resources policies and laws as well as in communicating relevant opportunities (e.g., water access options) and/or incentives (e.g., federal or state grants) for farmers to overcome the barriers associated with and uncertainty related to such climate change adaptations. ● The research targets mainly the agricultural communities within the state of Alabama, with special focus on small farm holders and historically disadvantaged groups, such as the African Americans in Alabama's Black Belt region. ● Further, the problem's framing places the onus for irrigation expansion on both farmers and other key stakeholders like extension agents, technical agents/irrigation service providers,

	representatives of local area businesses, among others, so, we will try to integrate the role of all the stakeholders involved in this process to better understand the challenges and prospects available for transitioning from rain-fed to irrigated agriculture. ● However, we do not plan to explicitly include policy makers or political leaders. Neither do we intend to model the political processes for implementing the strategies, nor the politics of unequal access to these strategies. ● Outputs mainly include the assessment of farmers' attitudes and perceptions towards climate change and current and anticipated coping mechanisms; identification of adaptation constraints and prospects for the farmers, specifically related to irrigation; characterization of dynamic adaptation pathways and deficits through agent-based and scenario modeling, all of which together will enable simulation of how, why, and when farmers do or do not adopt such adaptive strategies. ● The scale of intervention is region- or community-level, whereas the scale of modeling is community-level. Yet, the scale of the narrative, i.e., that agricultural communities are vulnerable to climate change related risks, frames the problem as one of global concern. ● The study is based on the notion that climatic disturbances, like seasonal precipitation and droughts, will challenge the resilience of agricultural communities in the coming years. In this regard, irrigation expansion is considered and projected to act as a primary adaptation against such climate associated risks. It is also the most common rural development strategy pushed by researchers, agricultural extension, and policymakers in Alabama for over two decades now. However, transitioning from rain-fed to irrigated agriculture has achieved limited traction within the state due to the complexities of farmers' irrigation decisions and disconnect with state-level incentives and technical/extension support. Therefore, we recognize the need to move beyond current biophysical and economic explanations of irrigation adoption, which have been used to inform irrigation expansion initiatives and state tax incentives over the last two decades. ● We assume that farmers have some agency to affect their own outcomes through their personal motivations and decision-making but are constrained (to some extent) by limited available opportunities or other external factors. As a result, it is absolutely imperative to move beyond the 'one-size-fits-all' approach that is not attentive to the diversity of Alabama farmers and their motivations and thus, expand research today to facilitate identification of the different barriers and incentives available to them that are needed to spur this transition.
3. Inputs	● The data for developing the model will come from a combination of personal interviews and household surveys of both farmers and other key stakeholders. The primary data will also be complemented with secondary information gathered from previously conducted studies, research reports, etc., that might represent historical patterns of inequities i.e. lacking in terms of representation of small or minority farmers within the state. ● Members of social disadvantaged communities are known to be systematically underrepresented in standardized data sources, such as the U.S. Census or USDA data, due to a number of factors, ranging from current or historical discrimination, neglect, and/or under provisioning of social services. As a result, such communities may not trust such data collection efforts and choose not to provide information. ● Many of the standardized data sets are used to make resource allocation decisions, such as state or federal funding or utility services like broadband, based on census information. In such situations, underrepresentation in the data leads to under-provisioning of services and opportunities, which can perpetuate existing socioeconomic inequalities.
4. Quantification	● Modeler subjectivity will be most obvious in the choices of what to include or exclude in the model. For example, we are developing a model to simulate farmer decision-making across the entire state of Alabama, however we cannot model every farmer and will need to define farmer types. Each agent type will then be associated with a set of behavioral models. Certainly the farmer types and associated behavioral models will simplify-away substantial heterogeneity, and those simplification choices will be based in part on categorizations evident in the broader literature. This will be countered somewhat by integrating insights from our community survey and interview efforts, but those methods cannot achieve full representational equity.
5. Interpretation	● Due to the inherent biases in standardized datasets (see section 3) and limitations of survey and interview methods (see section 4), calibration and validation will replicate those same biases when specifying parameters or selecting 'best performing' model outcomes based on comparison with empirical data.

	● Communication of unexpected results could be problematic if those results challenge established and biased perceptions of certain communities. This increases the burden of proof to demonstrate that unexpected results are not model artefacts, and may in part have been produced by the explicit attention to representational and procedural equities. ● Although the original purpose of the model is to produce realistic scenarios of adoption of climate adapted farming practices, any representational and distributional equity issues that come to light during the model interpretation need to be brought to the foreground. Otherwise, our modeling findings might be used to reinforce current water management and agricultural support policies that have not addressed inequities among Alabama farmers.

Example 4

These reflections relate to a stylistic agent-based model of smallholder farmer livelihoods, which aims to examine the emergence of food insecurity in pastoralist communities.

Theme	**Reflections**
1. Positionality	● Positionality ○ Main author: European, white, male, Postdoctoral research at research institute in Germany ○ Research team: 1 female Postdoc (white, European), 1 male Postdoc (white, Canadian) ○ Research institutes: 1) Helmholtz Centre for Environmental Research - UFZ: predominantly white, 2) International Livestock Research Institute (ILRI): mixed ○ Principal researcher is in a privileged position due to his education, academic training, etc. → positivist research paradigm ○ Mainly influenced by a particular school of thought, e.g. social-ecological systems, resilience thinking, etc. → the study has been conceptualized based on these principles ● Relation to research context ○ i) Outsider perspective: No direct experience of the situation in the studied research area, i.e. only external view (partly through one of the members of the research team who has experiences in the study area) → most information about the study area have been gathered from scientific experts or literature ○ ii) Modeler perspective: in addition to i), the principal researcher approaches the research question using a systems perspective that aims at representing only the main variables and influence factors relevant for the research questions, which may introduce potential bias (see also "Potential biases" in section 4. Process quantification) ○ Study area has experienced ongoing social, political, economic and cultural changes in recent decades, which have shaped the livelihoods of smallholders in the study area and also possibly inequities
2. Framing	● Narratives: Pastoralists and their livelihoods are challenged by effects of climate change and changes in livelihood strategies, which may lead to negative effects such as food insecurity → these negative effects should be mitigated. However, for the current study, we were mainly interested in *how* these negative effects may emerge, only partly in ways to reduce them ● Solutions: Our research question was mainly aimed at understanding the phenomenon of vicious circles, not yet at identifying solutions that can help to mitigate / avoid them. We propose some first ideas on how a better coexistence of pastoralism and crop farming might be achieved, e.g. by a better control of who is allowed to cultivate, where cultivation is allowed to take place and to what extent → this needs to take into account local customary land use rights, or local land use planning initiatives in order not to come in as a "top-down external intervention" ● Actors: ○ Smallholders, depending on livestock and/or crop farming for their consumption. ○ Many simplifying assumptions have been taken for modelling reasons and the research questions that we are interested in, e.g. no differentiation of ethnocultural groups, as we assume that there is no difference in land use between these groups; also we lack more detailed knowledge about cultural diversity in this region

	○ One assumption: reasons for households to expand their cultivated area are manifold, such as claiming land or diversification of livelihood strategies, (evident both from literature as well as knowledge of cooperation partner), but we focus on food insecurity only as the main reason ● Theories: The model is based on the assumption that household livelihoods depend on livestock and crop farming, which are both dependent on the natural resources available, i.e. mainly land. Environmental dynamics are driven mainly by climate. Households have agency in how they use the land, mainly by deciding where to move their livestock and the option to increase their cultivated area
3. Inputs	● The model is mostly based on qualitative knowledge from scientific experts (i.e. no local stakeholders) and literature, these could of course be biased. ● Some data from the IBLI Borana household survey have been analyzed and used to parameterize the model (average livestock numbers per household) and derive model rules (expansion of crop area not dependent on livestock numbers) ● No data specifically related to equity was used ● For the IBLI data, we need to check who has been surveyed (probably the household head) → however, for the information used from the data, this is also not that relevant
4. Quantification	● Model variables ○ Choice of food security as main output measure was mostly a model practicality decision: easier to handle than individual measures for consumption and also intuitive to understand ○ The threshold of food security = 1.0 is subjective as it assumes a specific caloric intake need per capita – this may of course differ by gender, age, location, etc. ○ Food consumption in the model is a stylized representation as it only assumes milk, meat (from cattle) and a single crop (maize) ○ Thus, there may be a mismatch between the theoretical understanding of food insecurity and our operationalization of it. ● Potential biases ○ The model uses several simplifying assumptions and does not include processes such as direct interactions between households, etc. However, these assumptions have mostly been taken for technical modelling reasons, as their inclusion would have made the model much more complicated and we deemed these processes as not important for the research question under consideration. ○ In an earlier stage of the model development, we planned to involve stakeholders in the modelling process as we intended to develop the model as a discussion tool that might be useful for land-use planning. We organized a stakeholder workshop in Ethiopia to which we invited stakeholders involved with land use planning (i.e. no farmers themselves), but realized our approach of developing a more stylized model was very difficult for them to understand, and that for a fully participatory process we would have needed much more resources (both financial as well as personnel) – therefore we decided to focus on a more general research instead (model purpose: system understanding / exploration). ○ We acknowledge that the model in its current form is therefore not suitable to be applied for any real-world decisions or to draw conclusions concerning food security for specific households.
5. Interpretation	● Calibration ○ We calibrated the model in such a way that we observe a particular share of food insecure households under given conditions (e.g., large number of households) → this was in implicit assumption taken as this is the behavior that we are interested in ○ However, this approach was mostly used to give us a baseline parameter set that "works well", as we did not have parameter values for several ecological parameters, not to calibrate or fit the model to a specific empirical dataset ○ Moreover, all households in the model are homogeneous, in particular they are equally endowed with livestock in the beginning of the simulation and have equal consumption

	needs. Therefore, we do not see that we have systematically misrepresented groups or superimposed a bias between food secure / insecure or poor / wealthy households. ● Model outputs and interpretation ○ The main motivation to start the project was driven by empirical observations of one of the team members that (uncontrolled) expansion of crop cultivation may lead to a "vicious circle" of increasing food insecurity due to shortages in pasture area and subsequent loss of livestock. However, we researchers also acknowledge that many households may rely on crop cultivation as their only income source. Thus, we did not form a preconception about crop cultivation being good or bad ○ → mainly interested under which conditions unintended/bad effects may outweigh the benefits of crop cultivation, and who is affected by these effects – this has shaped the storyline of the paper and the selection of results that are presented in the paper

Appendix 2: Full Scopus Search Results and Descriptive Statistics

Table A2-1

Category	Details	Number of articles
General information		
System	Built environment (e.g., transportation, housing, energy systems)	38
	Health (e.g., HIV/AIDS, infectious disease)	32
	Culture and game theory (e.g., cooperation, evolution, anthropology, ultimatum games)	27
	Environment (e.g., land-use, water systems)	21
	Economy (e.g., wealth, markets, business)	18
	Science and education (e.g., peer review, teaching)	6
	Crime (e.g., policing, incarceration)	4
	Other	9
Location	Not stated or aspatial	79
	North America	35
	Asia	11
	Europe	6
	Africa	3
	Global	3
	Oceania	2
	Central and South America	2
Journal	JASSS	10
	Lecture Notes in Computer Science	6
	Computers, Environment, and Urban Systems	4
	Other	120
Between whom? (subject)		
	Economic capital (wealth, income)	36
	Race	20
	Other forms of capital (e.g., social status, resource access)	16
	Socioeconomic (i.e., combined social and economic)	12
	Spatial (e.g., neighborhood, country)	11
	Gender	8
	Decision-making characteristics (e.g., altruism, cooperativeness)	7
	Stakeholder groups	6
	Other	9
Of what? (object)		
	Access to services (e.g., housing, energy, travel time)	40
	Health outcome (e.g., HIV/AIDS, influenza, diet)	23
	Wealth or income	22
	Environmental (e.g., water quality)	9
	System-level outcome (e.g., equilibrium, emergence of cooperation)	8
	Social (e.g., group membership, status, genetic selection)	7
	Other	18
Fairness principle		
	Vulnerability/need	38
	Equality	32
	Disparity†	13
	Merit	3

Category	Details	Number of articles
† We interpret 'disparity' as a lens that implicitly views differences between groups to be undesirable and—particularly with respect to race in the United States—to be a result of historical structural inequities.		

Table A2-2: Full list of references included within the review.

Dimension of justice	Approach	References
Recognitional (n=4)	Implications of representing vulnerable group characteristics (e.g., incorporating gendered or race-specific decision-making and behavior) (n=4)	(Adiga et al. 2018; Beal Cohen et al. 2019; Goodreau et al. 2017; Villamor & van Noordwijk 2015)
Procedural (n=41)	Individual decision-making processes (e.g., agents with fairness objectives) (n=20)	(BenDor et al. 2009; Bianchi et al. 2018; Bo & Yang 2010; Chen & Gostoli 2016; Dávid-Barrett & Dunbar 2014; Ebenhöh & Pahl-Wostl 2008; Jaffe 2002; Li et al. 2013; Mahault et al. 2017; Motchoulski 2021; Nawa et al. 2002; O'Connor 2017; Ponsiglione et al. 2015; Proietti & Franco 2018; Schank et al. 2015; Schindler 2012; Squazzoni & Gandelli 2012; Takesue 2017; Xianyu 2010; Zuo et al. 2009)
	Group interactions (e.g., cooperation, power dynamics) (n=13)	(Back & Flache 2006; Beal Cohen et al. 2019; Debove et al. 2015, 2017; Delay & Piou 2019; Dyble et al. 2015; Klein et al. 2017; Levy et al. 2018; Mahault et al. 2017; Motchoulski 2021; Patrzyk & Takáč 2017, 2017; Sánchez & Cuesta 2005; Schank et al. 2018)
	System-level decision-making processes (e.g., resource allocation) (n=5)	(Dray et al. 2005; Eckerdce et al. 2017; Meng et al. 2018; Sobkowicz 2016; Sreekanth & Roy 2017)
	Governance (multiple agents collaborating on a decision) (n=4)	(Choi & Robertson 2014; Farhadi et al. 2016; Motchoulski 2021; Zellner et al. 2014)
	Simulation methodology (i.e., ordering of agent processes) (n=2)	(Page 1997; Welch & Ekwaro-Osire 2008)
Distributional (n=117)	Distributional effects by group identity (e.g., race, spatial location) (n=60)	(Adams et al. 2018, 2021; Adiga et al. 2018; Beck et al. 2015; Bell et al. 2016; Campbell et al. 2014; Cerdá et al. 2014; Chandra-Putra & Andrews 2020; Chang et al. 2020; Chao et al. 2015; Choi & Robertson 2014; Combs et al. 2020; Costa et al. 2021; De Freitas et al. 2017; Dyer & Nijnik 2014; Eckerd 2015, 2013; Eckerdce et al. 2017; Escudero et al. 2017; Evans et al. 2019; Giorgione et al. 2021; Goedel et al. 2018, 2020; Gong et al. 2016; Goodreau et al. 2017; Gouri Suresh & Schauder 2020; Gulden 2013; Gurram et al. 2019; Heaton et al. 2020; Henry & Brugger 2017; Jin et al. 2018; Kim et al. 2014; Kogut et al. 2014; Koh et al. 2019; Langellier et al. 2017; Lum et al. 2014; Malik et al. 2015; Matthews et al. 2012; Mittal et al. 2019; Nandi et al. 2017; Nelson et al. 2015; Oh et al. 2020; Orr et al. 2014, 2016; Orsi 2019; Paleti et al. 2016; Potter et al. 2012; Purnomo et al. 2013; Sælen 2016; Shin & Bithell 2019; Shrime et al. 2016; Singh et al. 2019; Singleton et al. 2020; Smart 2019; Sreekanth & Roy 2017; Tarekegne & Rouleau 2019; Tomasiello et al. 2020; Wang et al. 2019; Williams et al. 2020; Yang et al. 2020b)
	Conditions leading to inequality (n=40)	(Auchincloss et al. 2011; Bianchi et al. 2018; Bruch 2010; Brugger & Henry 2019; Cao et al. 2019; Chen & Gostoli 2016; Choi 2018; Dávid-Barrett & Dunbar 2014; de Wildt et al. 2020; Dekker 2019; Delay & Piou 2019; Dyer & Nijnik 2014; Eckerd 2015; Eckerd et al. 2012; Ellis et al. 2012; Flaig & Houy 2019; Gaus 2018; Guazzini et al. 2019; Hauser & Schredelseker 2018; Homa et al. 2015; Janssen & Rollins 2012; Klein et al. 2017; Levy et al. 2018; Li et al. 2012; Lum et al. 2014; Mahault et al. 2017; Martell et al. 2012; Meng et al. 2018; Metcalf 2016; Montes 2012; Motchoulski 2021; O'Connor 2017; Ponsiglione et al. 2015; Schank et al. 2018; Schindler 2012; Vallejos et al. 2018; Wang et al. 2016; Wicaksono & Mansury 2020; Yang et al. 2015; Zheng et al. 2019)

Dimension of justice	Approach	References
	Distributional effects over population (e.g., Gini index) (n=17)	(Ari & Koc 2019; Barbati et al. 2011; BenDor et al. 2009; Blikstein et al. 2008; Chen et al. 2010; Dominick 2007; Filatova et al. 2011; Gath et al. 2012; Hawick 2014; Heckbert 2011; Jaffe 2002; Le Bars & Attonaty 2001; Mohan & Kumar 2009; Suslov et al. 2016; Wangmaeteekul & Budgen 2011; Winter et al. 2021; Yang et al. 2020a)
	Implications of inequality (n=5)	(Cardaci 2018; Kustov 2017; Sakaki 2019)

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