Aspiration adaptation, poverty and agricultural management: an agent-based modelling study

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Abstract. To design more efficient and equitable agricultural technologies and policies, we need to understand why individuals do not act in line with the expectations of researchers and policy makers, and we need to understand how and why interventions exacerbate existing inequalities. Both can be understood by exploring how aspirations influence households' future-oriented behaviour. This paper does so by introducing the 3spire model, which integrates three aspirational dimensions: income, food self-sufficiency, and leisure, and by examining how aspirations adapt, shift and influence households' behaviour over time. The 3spire model incorporates aspiration adaptation theory to simulate agents' farm management decisions and performance over time. Agents, representing farming households, interact within a social network and consider alternative future plans iteratively, choosing the first satisficing plan. Preliminary findings indicated that initial wealth influenced aspiration dynamics. There was, however, great heterogeneity in these aspiration dynamics, also among households with similar levels of initial wealth, suggesting additional factors at play. Further research should investigate other types of non-monetary wealth and incorporate context-specific data to inform targeted policies and interventions, fostering equitable rural development and reducing poverty and inequality.

Keywords: Satisficing, Ethiopia, smallholder farming, land use, food security

1 Introduction

Rural households are often the focal actors in food insecurity alleviation efforts[1]. They are targeted with technologies and policies but in many geographic settings, such as Ethiopia[2] and Peru[3], associated productivity gains[4, 5], and therefore food security gains, remain below their anticipated potentials, and tend to benefit richer households more than poorer ones[6]. To design more efficient and equitable technologies and policies, we need to understand why individuals do not act in line with the expectations of researchers and policy makers, and how and why interventions exacerbate existing inequalities. Both can be understood by exploring households' diverse and context-specific aspirations, and how these aspirations influence their future-oriented behaviour[7, 8].

Aspirations are hopes or ambitions of achieving something. As defined by Bernard & Taffesse (2014) [9]: i) they are future oriented, but do not include the desire for immediate gratification, ii) they are hopes and ambitions that individuals are intrinsically motivated to invest time in (not idle daydreams), and iii) when combined, they form individuals' ambitions to realise multi-dimensional life outcomes. Aspirations have been shown to reliably predict future oriented behaviour in fields ranging from education[10], to social relationships[8], migration[11], business[12], and farming[13].

Aspiration adaptation theory is a psychological theory that describes how individuals' aspirations change because of their life experiences and circumstances[14, 15]. It states that individuals initially set aspirations based on their expectations and desires. If they are unable to achieve these aspirations, however, they may adjust their aspirations downwards to match their perceived opportunities and the available resources. Conversely, if individuals achieve results beyond their aspirations, they may adjust them upwards[16]. The decisions individuals make about the future are driven by their aspirations. They aim to meet the aspirational thresholds they have (implicitly) set for each aspirational dimension. They will consider different future plans until they are satisficed, and then select that plan regardless of it not necessarily being the best possible they are simply aiming for a plan that is "good enough"[15]. This decision-making strategy, which is often contrasted to optimising (selecting the best plan), is termed satisficing, a portmanteau of satisfy and suffice[17]. Satisficing is rational, because the search for solutions in itself is costly[18]. When poverty results in poor performance (e.g., low income due to low yields due to lack of inputs), the lowered aspirational thresholds can cause people to stick with or select suboptimal future plans even though better options become available to them[19, 20]. This is called aspiration failure, and it is a behavioural poverty trap that on a population level can lead to exacerbated inequalities[16].

Our aim is to illustrate how the combined key insights from aspiration adaptation research can be captured in agent-based modelling studies that explore this behaviour and its consequences on rural households and communities. Here, we illustrate how the proposed model can be used to explore the question whether differences in initial wealth lead to different aspiration dynamics?

1.1 Five key insights from aspiration adaptation research

Aspirations and aspiration adaptation have been explored in both theoretical[14, 16, 21], experimental[8, 12], observational[9, 22], and modelling studies[23–25]. Though research is in the early stages in all four approaches, developing the modelling approach further is crucial, as models, agent-based models (ABMs) in particular, are well suited to explore phenomena and interventions involving individual behaviour and interactions and their population-level consequences. Through the creation of heterogenous agent populations that resemble real populations, rules representing aspiration adaptation and aspiration-based decision making, and spatial layers that represent a real spatial environment, ABMs enable scientists to explore and compare different policy interventions[26] and socio-ecological phenomena[27]. As the key insights from theoretical, experimental and observational studies on aspiration adaptation have not yet been captured by existing models, however, this potential remains unexplored.

Key insights from theoretical, experimental and observational approaches that remain to be explored are: aspirations are multi-dimensional[28]; individuals consider different future plans iteratively, and select the first plan that is "good enough"[15]; aspiration thresholds are dynamic[28] and aspirations are adjusted in response to past aspirations and past performance[12]; and individuals are chronically optimistic[12]. Thus far, no agent-based modelling studies simulating the behaviour of rural households have combined these insights. Most studies have been one-dimensional, considering only one aspirational dimension, relating to either productivity[18, 23, 29] or profit[24, 25, 30]. Most studies have also assumed that aspiration thresholds are static[18, 23, 29–31] or respond only to externalities, such as market[25] and climate[25]. Furthermore, no studies have reflected that people are chronically optimistic.

Lastly, modelling studies have implemented the process whereby individuals consider future plans in roughly three ways, two of which, we argue, do not follow aspiration adaptation theory. Firstly, some modelling studies let their agents select a randomly drawn future plan each time their aspiration thresholds are not met. This means that agents may settle for plans that are worse than the situation they were in to begin with, implying that agents are irrational. Both irrationality and shifting to other less-than-satisficing solutions when status quo is preferable, go against the premises of aspiration adaptation theory[15]. Secondly, some modelling studies let their agents select the best potential solution each time their aspiration thresholds are not met[31]. This makes their agents optimisers, not satisficers as aspiration adaptation theory dictates[15]. The third suite of models loop through future plans sequentially in order of familiarity, and select the first satisficing solution considered[32]. This is in line with aspiration adaptation theory but has not been implemented in modelling studies in a food system or rural livelihood context, where the models that loop through future plans sequentially do so in a random order[23, 30].

2 Methodology

2.1 Model design

We built an agent-based model to explore how aspirations adapt over time in response to and along with farmers' decisions, and with changes in their personal circumstances and environment. We named it 3spire because it has three aspirational dimensions: food self-sufficiency, income, and leisure. Income was defined as the earnings from minus costs of agriculture: food self-sufficiency was defined as the amount of maize equivalents consumed: and leisure was defined as the amount of time not spent working or sleeping, all per household. 3spire has a spatial environment, agents, and a social network connecting the agents (Fig. 1). Agents' future behaviours are informed by agents' past performance, their aspirations, by other agents in their social network, and by their spatial environment (e.g., soil, market access, climate). The current version of the model only has an agricultural land use layer, including grains, perennial cash crops (coffee) and annual cash crops (onions). Yields per unit of land and applied fertiliser, and profits per unit harvested crop are consistent over time and space.

The modelled agents are farming households with one household head each. The households own different types of assets such as land, money and cattle, and they have specific (collections of) production options. They may, for example, grow maize with moderate levels of inorganic fertiliser and own three cows. The households also have a specified number of family members, of which the age and gender is known. The household head has knowledge and experience of their past and current production systems, and aspirations.

The social network that connects the households to each other is static. It is initialised using empirical data for network size, and uses similarity in household characteristics as a predictor of inter-household connections[33]. Knowledge is exchanged through this social network: if agents try something new, they will share the experience they gain with everyone in their social network.

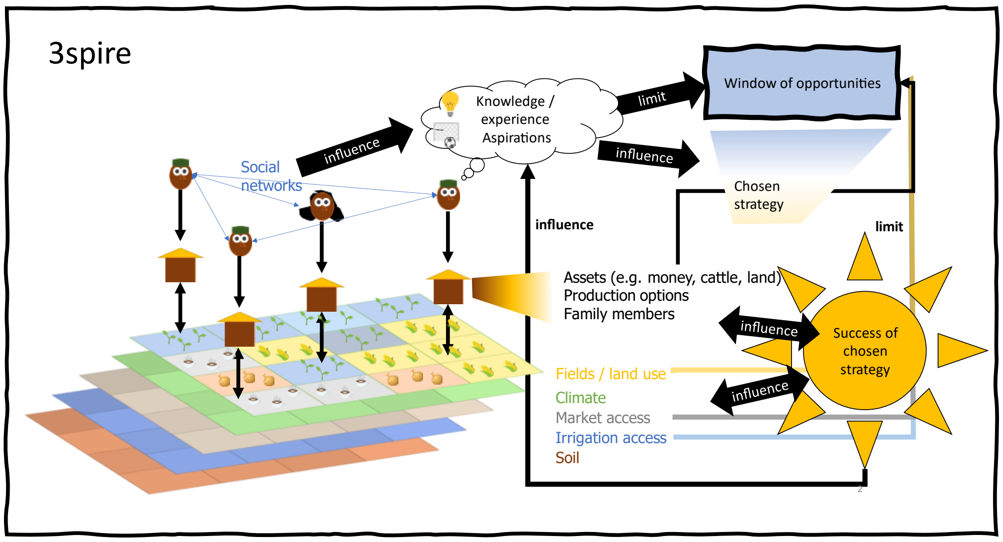

Figure 1. A diagram of our envisioned agent-based model, 3spire

2.2 Implementation of aspiration adaptation

Initial aspirations

Through a series of expert workshops held at the universities of Hawassa and Bahir Dar, Ethiopia (25.11.2022 – 8.12.2022, with a total of 41 participants over 7 workshops), three aspirational dimensions were selected as being most relevant to farmers' future behaviour: income, food self-sufficiency, and leisure. Initial aspiration thresholds were set based on survey data (Table 1). Initial income aspiration thresholds were sampled from an exponential distribution fitted on data from a survey by Mekonnen and colleagues[34]. Initial food self-sufficiency and leisure thresholds were sampled from normal distributions fitted on data from a survey by Tesfaye and colleagues. Both surveys used the measurement approach proposed and validated by Bernard & Taffesse (2014)[9]. The distributions were parameterised in R using the maximum-likelihood fitting function fitdistr from the MASS package[35], and the parameterised distribution with the lowest Akaike Information Criteria was selected as the best model[35].

Table 1. Descriptive statistics of data used to determine initial food self-sufficiency, income, and leisure aspiration thresholds.

		Aspired	Present	Unit	Fitted distribution	N
Food self-sufficiency	Mean Median	69.0 75.0	62.6 60.0	Kg per household per week	Aspired = Present + *normal(6.91,26.99)*	390
Income	Mean Median	163,115 100,000	46,901 35,000	ETB per hours per year	Aspired = Present + *exp(0.86) * 100,000*	675
Leisure	Mean Median	3.78 4.00	2.79 3.00	Hours per household head per day	Aspired = Present + *normal(0.98,1.68)*	390

Updating aspiration thresholds

In the model, households start each year by evaluating last year's performance. If they are satisficed, i.e., if they have managed to perform well enough to meet their aspiration thresholds, they continue to farm as they did last year. If they are dissatisficed, they consider alternative plans. Alternative plans that are similar to their current management will be considered first. Similarity is based the overlap in skills and resources required to implement a new plan. The first alternative plan household heads are satisficed with is selected, and management is adapted and implemented accordingly. Alternative plans may, e.g., be growing more maize to be food self-sufficient or buying supplementary cattle feed to earn money from dairy production. Which opportunities agents have (i.e., their window of opportunities, Fig. 1) is limited by their knowledge, assets, current management, and spatial environment. If a household does not have sufficient labour to cultivate vegetables, for example, this strategy will not be part of their window of opportunities. Their performance when trying something new is also influenced by their assets, current management, and spatial environment. Once implemented, new plans will give their implementers and their social network knowledge of the existence of and expected outcomes from the new management. Depending on how successful a plan is, it may cause agents to adapt their aspirations. New aspiration thresholds are calculated based on past aspirations, past performance, and optimism. The formula we use for calculating new aspirations is:

$$AT_{a\,t} = AT_{a\,t-1} * optimism - b * AG_{a\,t-1}$$

where *AT* is the aspiration threshold of an aspirational dimension *a* at time *t*, *AG* is the aspiration gap, i.e. the difference between the aspired threshold and the actual outcome along an aspirational dimension *a*, *optimism* is a variable that determines how optimistic (or pessimistic) household heads are, and *b* is a constant that reflects how much of the aspiration gap should be closed each year. *optimism* and *b* can be calibrated to reflect local circumstances when applying the model to specific regions. The formula was selected from an experimental study that compared the fit of models for aspiration adaptation to time series observations[12].

2.2 Data, simulation, and analysis

3spire consists of three types of agents: farming households, cattle, and fields. Households are connected to each other through social networks, and to their cattle and fields through ownership. Cattle are connected to their calves through birth. The agents have characteristics, abilities and can make decisions, all of which are as described in the Table 2. We distinguish abilities from decisions, where abilities occur automatically, independent of agents' aspirations, while decisions are plans that agents may implement to fulfil their aspirations.

The model consists of 100 randomly selected households, that own a total of 232 fields and 482 cattle at the start of the simulation. The households reflect real households surveyed in 2018-2019 by the Central Statistical agency in Ethiopia[36]. Their characteristics, either attributed to the households directly (e.g. household size), or to their household heads (e.g. knowledge of farm systems), their fields (e.g. field size), or their cattle (e.g. sex), were used as reported or, in case of missing values, approximated using linear interpolation [37]. The model was run for 23 timesteps, representing one year each, with *b* set to 0.45 and *optimism* to 1.05.

Table 2. Agent characteristics, abilities and decisions

Households		
	Characteristics	
		Knowledge of farm systems, management practices and technologies
		Aspiration thresholds
		Memory of aspiration thresholds and outcomes in previous years
		Wealth
		Family members (with associated ages and genders)
		Family dietary needs
		Cattle
		Fields
		Current farm management
	Abilities	
		Gain knowledge of new managements tried by agents in social network
		Adapt aspirations
		Consume produce
		Sell produce
		Buy produce
	Decisions	
		Change land use
		Apply (more) fertiliser
		Feed cattle supplementary feed
		Buy (more) cattle
		Sell cattle
Fields		
	Characteristics	
		Size
		Land use (maize, pasture, perennial cash crop, annual cash crop or fallow)
		Fertilizer level
	Abilities	
		Grow produce
Cattle		
	Characteristics	
		Sex
		State (dry / in lactation / pregnant)
		Calves
		Feed source
	Abilities	
		Lactate
		Give birth
		Eat
		Die

We analysed the aspiration outcomes from year 3 onwards (time zero), to allow agents to settle after initialisation. The households were classified into 4 different wealth groups, roughly representing the lower quartile, the middle quartiles, the upper quartile, and the upper 10% of the households (Table 3). The first group was in debt, the second group had between 0 and 50,000 Ethiopian birr (ETB), the third group had between 50,000 and 250,000 ETB, and the fourth group had more than 250,000 ETB (Fig. 2). The dynamics and changes in aspiration thresholds, outcomes and wealth over time were analysed by means of descriptive statistics. Inflation was not accounted for in the simulation or the analysis of the results.

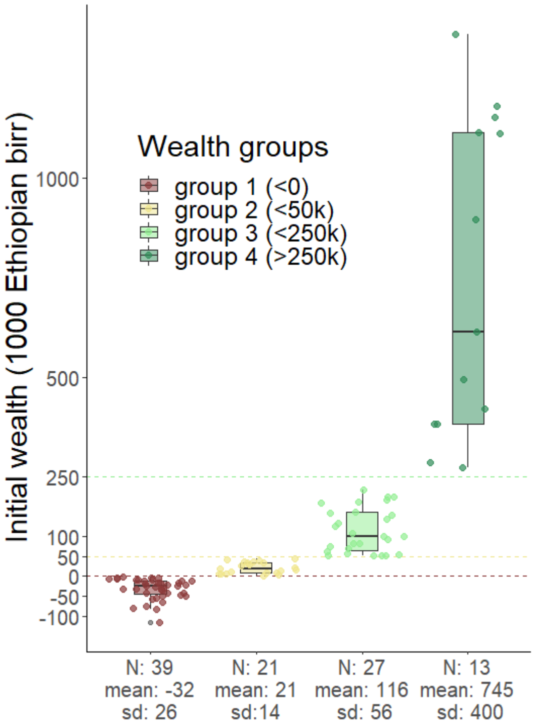

Figure 2. The initial wealth of households from different wealth groups at the beginning of the simulation.

3 Preliminary results

At the beginning of the simulation, the average household had 103,000 ETB. 20 years later, this has increased to 969,000 ETB. This increase in wealth was, however, not distributed equally across households. The increase occurred in the 25 richest households, and even more strongly in the 10 richest households (Table 3). There was, however, a large heterogeneity in outcomes. One household that started out with debts managed to increase its wealth substantially, while some households starting out with thousands of ETB lost all their money and ended up indebted (Fig 3).

Table 3. Descriptive statistics of cumulated household wealth (in 1000 ETB) at the start and at the end of the simulation.

	Mean	Sd	10%	25%	50%	75%	90%
Time zero	120	288	-42	-18	20	112	383
20 years later	969	2588	-437	-263	39	803	3448
Increase	849	2300	-394	-245	20	691	3065

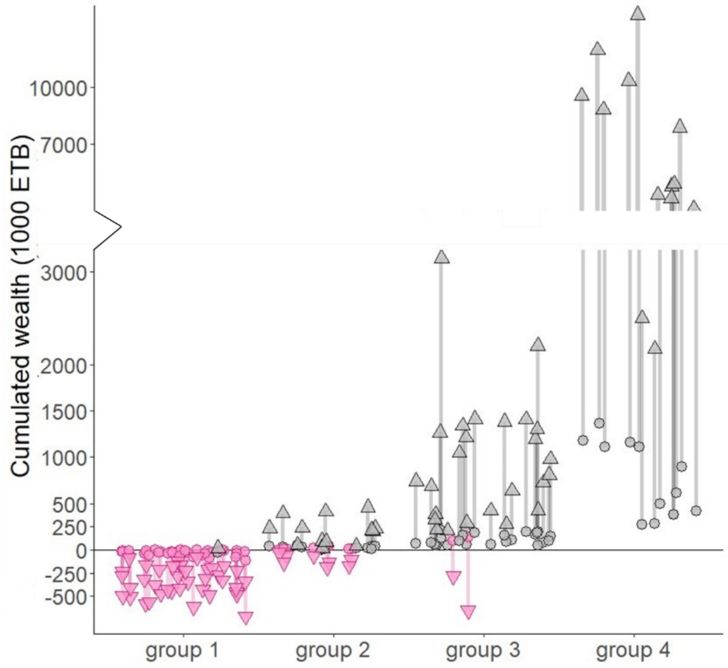

Figure 3. Cumulated wealth per household at the beginning (round dot) and the end (arrow head, 20 years later) of the simulation, given in 1000 ETB. Each arrow represents a household, and they are grouped according to wealth class.

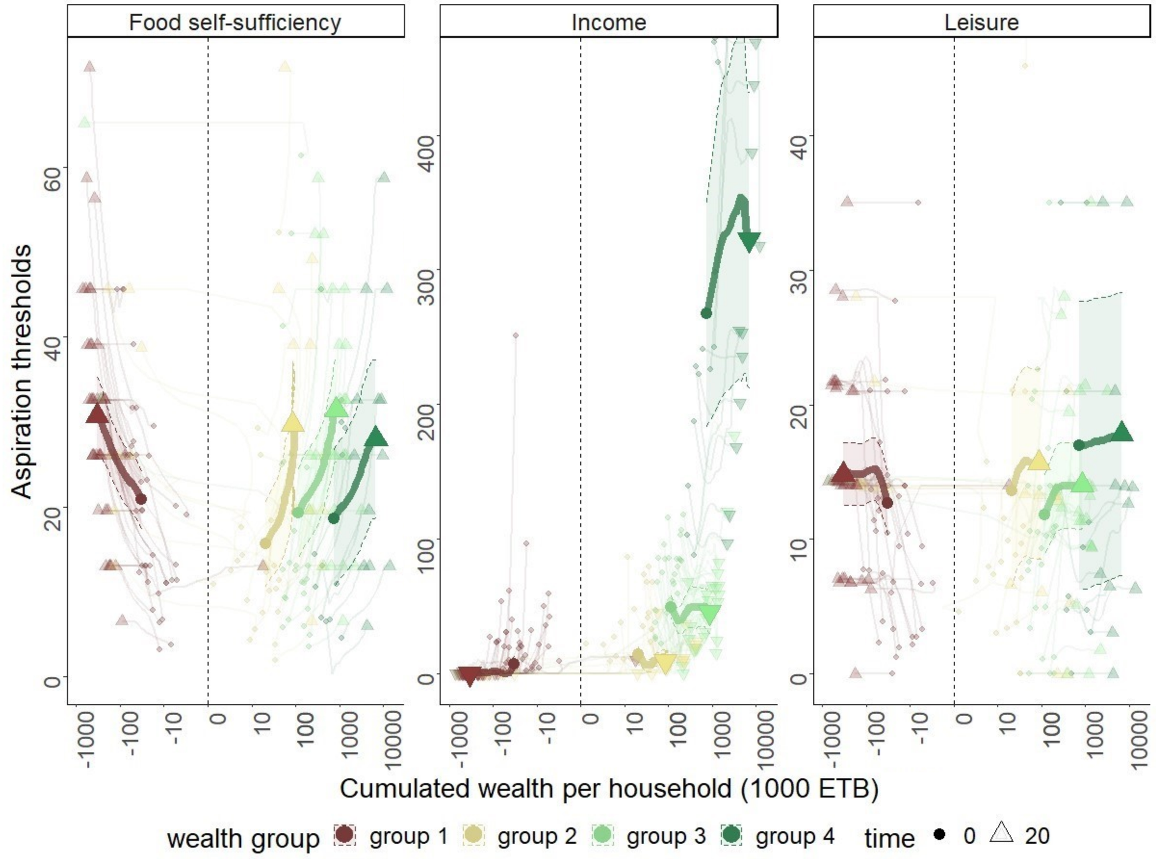

Figure 4. Aspiration threshold dynamics over wealth, by wealth group. Each thin line represents an individual household, while the thick lines represent the average household by wealth group. The round dots mark the start of the simulation and the triangles the end. The shaded areas in between the dashed lines represent the 95% confidence intervals of the average trends. The units of food self-sufficiency, income, and leisure, respectively, are maize consumption (kg per household per week), ETB per household per year, and 8-hour person days not spent working or sleeping per household per week. For income and leisure, an upper axis limit is set to more clearly visualise average trends, excluding some households with very high aspiration trends.

We then explored whether these initial differences in wealth (Fig. 2) affected the way aspirations were adapted over time (Fig 6). We found that income aspirations and actual incomes decreased over time for all groups but the wealthiest. Among the wealthiest, income aspirations increased in the first half of the simulation before they started dropping as well (Fig. 4). Leisure aspirations also differed across wealth groups. For all wealth groups but the wealthiest, there was an initial increase in aspired leisure, then a flattening off. For the wealthiest group, thresholds increased continuously, but very slowly (Fig. 4). For food self-sufficiency, aspirations dynamics did not differ substantially across groups. As with the change in wealth over time (Fig. 2), however, the change in aspirations over time was also subject to great heterogeneity (Fig. 4), that cannot be explained by differences in initial monetary wealth only.

4 Discussion

In this article we asked: Can differences in initial wealth lead to different aspiration dynamics? Theoretically, we expected that it would, because wealth enables people to have wider windows of opportunities; they can make changes to the way they manage their farm that require (large) investments[13, 16]. We found that over time, differences in wealth between households increased (Fig. 3). Generally, wealthier households benefitted, while the poorest quartile became poorer (Table 3). Households with increasing debts all had small land sizes. The cause of their debts were food purchases, as they were not able to fulfil their household needs from their own production. As has also been observed in empirical studies, the absence of liquidities left them unable to increase their yields through fertiliser purchases, and their other means of production (their cattle) were sold early on in the simulation to buy food[38]. The only household that managed to escape poverty in the indebted group did so because it had a small plot of coffee that generated enough money to cover its food purchases (Fig. 3). A lack of knowledge about coffee production constrained more households from doing the same[39]. We do, however, expect that in reality many of the households would not have found themselves in the huge debts we simulated because they would have received money, food, labour and/or draught power from off-farm sources; Ethiopian society knows many different formal and informal safety nets[40]. The dire predictions of our model illustrate the importance of maintaining and strengthening these.

Some households wound up indebted despite of having substantial liquidities at the start of the simulation (Fig. 3). These households typically started out having or buying cattle and growing maize, and then – at some point during the simulation – changed from maize to pasture in order to gain more leisure, buying their maize instead of growing it (Fig. 3). They became indebted if, and only if, they did not manage to maintain their herd. Some of the richer households also went into debt because they invested in growing coffee, but these investments would have paid off over time[39].

We found that groups with different initial levels of wealth differed in their aspiration dynamics (Fig. 4). Thresholds for income tended to increase with high and increasing wealth and decrease with low and decreasing wealth, in line with theory[14] and empirical research[41]. We were, however, surprised to see that even the second richest group of households reduced their income thresholds over time. The decrease co-occurred with a decreasing availability of options to improve farm management. Once households applied high levels of fertiliser, had selected the best land use available to them, and bought or bred as many cattle as their land could support, there were no more ways to keep increasing their income. In reality, there more are options available to farmers, such as crop rotation, application of herbicides, and post-harvest processing[42]. These will be added in future versions of the model.

Households' time for leisure was very high at the beginning of the simulation. This was in part because much of the rural workforce is underemployed, amongst others because of the limited amount of land available[10]. As we assumed that households do not want to be fully unemployed, we put an upper limit to the desired amount of leisure per household member. Many of the households in our simulation reached that upper limit within the simulation period; this explains the stabilizing leisure aspiration trend. Our model does, however, only consider on-farm agricultural labour. In reality, households also travel to markets to source inputs and sell outputs[36, 43], engage in off-farm work[36, 44], and perform housework such as cleaning, cooking, and harvesting water and firewood[36, 45]. Not including the labour of these activities makes us underestimate household labour, which may have resulted in an underestimate in the importance of the aspiration for leisure in households' decision-making.

Food self-sufficiency aspirations increased independently of wealth. This was possible because there was no feedback between the food demand and supply; we assumed maize could be purchased in the market at any time and that prices would be stable. Though this may be true for certain fertile regions in Ethiopia, it has not been the case for most of the population, due to, amongst others, droughts[46], plagues[47], post-harvest losses[48], and poor market access[43]. This will also be accounted for in future versions of the model.

To get a better understanding of the underlying farm management decisions that caused the observed patterns in aspiration dynamics, and of the robustness of these patterns, further research is needed on the choices that different households make in different circumstances, and on the influence of parameters such as yields, labour requirements, and prices. The realism of the decision-making processes and the aspiration dynamics of the households could be developed further, e.g. by adding cognitive biases such as recency and primacy biases[49], and social comparison[14, 22], respectively. Further research should also investigate other types of non-monetary wealth, such as land and livestock, and incorporate context-specific spatial data to inform targeted policies and interventions[26], fostering equitable rural development and reducing poverty and inequality.

5 Conclusion

The 3spire model provides a valuable tool for understanding and exploring the influence of aspirations on rural households' behaviour and performance. By incorporating multiple interlinked aspirational dimensions, and the dynamic, path-dependant process of aspiration adaptation, the model enables researchers to explore how interventions and policies can be designed to promote more effective and equitable rural development and thereby help break the cycle of poverty and inequality. To design and assess the impact of policies in specific regions, there is however a need for context-specific time series data, addition of representative spatial layers and their influence on yields and revenues, and calibration and addition of the context specific decisions farmers can make in order to improve their farm management in line with their aspirations.

6 Open data

3spire, and the scripts that used to parameterise and calibrate the model and analyse the model outputs can be found on:
https://github.com/ateeuw/3spire_socialsimulationconference

References

1. Mausch K, Harris D, Heather E, et al (2018) Households' aspirations for rural development through agriculture. Outlook Agric 47:108–115. https://doi.org/10.1177/0030727018766940
2. Assefa BT, Chamberlin J, van Ittersum MK, Reidsma P (2021) Usage and impacts of technologies and management practices in ethiopian smallholder maize production. Agric 11:1–19. https://doi.org/10.3390/agriculture11100938
3. Stroosnijder L, Posthumus H (2010) To terrace or not : the short-term impact of bench terraces on soil properties and crop response in the Peruvian Andes. Environ Dev Sustain 12:263–276. https://doi.org/10.1007/s10668-009-9193-4
4. Loevinsohn M, Sumberg J, Diagne A, Whitfield S (2013) Under what circumstances and conditions does adoption of technology result in increased agricultural productivity? A Systematic Review Prepared for the Department for International Development
5. Glover D, Sumberg J, Andersson JA (2016) The adoption problem; or why we still understand so little about technological change in African agriculture. Outlook Agric 45:3–6. https://doi.org/10.5367/oa.2016.0235
6. Thuijsman ES, den Braber HJ, Andersson JA, et al (2022) Indifferent to difference? Understanding the unequal impacts of farming technologies among smallholders. A review. Agron Sustain Dev 42:. https://doi.org/10.1007/s13593-022-00768-6
7. Gsottbauer E (2013) Behavioral Economics and Environmental Policy: Theory and Experiments. Uniersitat Autònoma de Barcelona
8. Tanguy Bernard, Stefan Dercon KO and AT (2014) The Future in Mind: Aspirations and Forward-Looking Behaviour in Rural Ethiopia. London
9. Bernard T, Taffesse AS (2014) Aspirations: An Approach to Measurement with Validation Using Ethiopian Data. J Afr Econ 23:189–224. https://doi.org/10.1093/jae/ejt030

10. Mussa EC (2020) Youth aspirations, perceptions of farming, and migration decisions in rural Sub-Saharan Africa: Further empirical evidence from Ethiopia. Bonn
11. Carling J, Collins F, Carling J (2018) Aspiration, desire and drivers of migration. J Ethn Migr Stud 44:909–926. https://doi.org/10.1080/1369183X.2017.1384134
12. Lant TK (1992) Aspiration Level Adaptation: An Empirical Exploration. Manag Scence 38:623–644
13. Mekonnen DA, Gerber N (2017) The Effect of Aspirations on Agricultural Innovations in Rural Ethiopia
14. Ray D (2006) Aspirations, poverty, and economic change. In: Banerjee A, Benabou R, Mookherjee D (eds) Understanding Poverty. Oxford University Press, Oxford, pp 409–422
15. Selten R (1998) Aspiration Adaptation Theory. J Math Psychol 42:191–214. https://doi.org/10.1006/jmps.1997.1205
16. Dalton PS, Ghosal S, Mani A (2016) Poverty and Aspirations Failure. Econ J 126:165–188. https://doi.org/10.1111/ecoj.12210
17. Simon HA (1956) Rational choice and the structure of the environment. Psychilogical Rev 63:129–138. https://doi.org/10.1136/bmj.j836
18. Gotts NM, Polhill JG, Law ANR (2003) Aspiration levels in a land use simulation. Cybern Syst 34:663–683. https://doi.org/10.1080/716100277
19. Nandi R, Nedumaran S (2021) Understanding the Aspirations of Farming Communities in Developing Countries: A Systematic Review of the Literature. Eur J Dev Res 33:809–832. https://doi.org/10.1057/s41287-021-00413-0
20. Bernard T, Dercon S, Taffesse AS (2011) Beyond Fatalism: An Empirical Exploration of Self-Efficacy and Aspirations Failure in Ethiopia
21. Genicot G, Ray D (2017) Aspirations and Inequality. Econometrica 85:489–519. https://doi.org/10.3982/ecta13865
22. Mekonnen DA (2016) Social Interactions and Aspirations Formation in Rural Ethiopia. Bonn
23. Dressler G, Groeneveld J, Buchmann CM, et al (2019) Implications of behavioral change for the resilience of pastoral systems—Lessons from an agent-based model. Ecol Complex 40:. https://doi.org/10.1016/j.ecocom.2018.06.002
24. Gotts NM, Polhill JG (2009) When and how to imitate your neighbours: Lessons from and for FEARLUS. J Artif Soc Soc Simul 12:
25. Rovere SL, North MJ, Podesta GP, Bert FE (2016) Practical Points for the Software Development of an Agent-Based Model of a Coupled Human-Natural System. IEEE Access 4:4282–4298. https://doi.org/10.1109/ACCESS.2016.2592418
26. Teeuwen AS, Meyer MA, Dou Y, Nelson A (2022) A systematic review of the impact of food security governance measures as simulated in modelling studies. Nat Food 3:619–630. https://doi.org/10.1038/s43016-022-00571-2
27. Niazi M, Hussain A (2011) Agent-based computing from multi-agent systems to agent-based models: A visual survey. Scientometrics 89:479–499.

https://doi.org/10.1007/s11192-011-0468-9
28. Appendurai A (2002) The Capacity to Aspire: Culture and the Terms of Recognition. In: Rao V, Walton M (eds) Culture and Public Action. The World Bank, Washington, DC, pp 59–84
29. Sanga U, Park H, Hammond C, Shah SH (2021) How do farmers adapt to agricultural risks in northern India? An agent-based exploration of alternate theories of decision-making. J Environ Manage 298:. https://doi.org/10.1016/j.jenvman.2021.113353
30. Polhill JG, Gimona A, Gotts NM (2013) Nonlinearities in biodiversity incentive schemes: A study using an integrated agent-based and metacommunity model. Environ Model Softw 45:74–91. https://doi.org/10.1016/j.envsoft.2012.11.011
31. Matthews R (2005) The People and Landscape Model (PALM): Towards full integration of human decision-making and biophysical simulation models. Ecol Modell 194:329–343. https://doi.org/10.1016/j.ecolmodel.2005.10.032
32. Wall F (2021) Modeling managerial search behavior based on Simon's concept of satisficing. Comput Math Organ Theory. https://doi.org/10.1007/s10588-021-09344-x
33. Laursen B (2017) Making and Keeping Friends: The Importance of Being Similar. Child Dev Perspect 11:282–289. https://doi.org/10.1111/cdep.12246
34. Mekonnen DA, Gerber N (2017) Aspirations and food security in rural Ethiopia. Food Secur 9:371–385. https://doi.org/10.1007/s12571-017-0654-6
35. Venables WN, Ripley BD (2002) Modern Applied Statistics with S, 4th ed. Springer, New York
36. Central Statistics Agency of Ethiopia, World Bank (2020) Ethiopia Socioeconomic Survey (ESS) 2018/19
37. Zeileis A, Grothendieck G (2005) zoo: S3 Infrastructure for Regular and Irregular Time Series. J Stat Softw 14:1–17. https://doi.org/10.18637/jss.v014.i06
38. Tadele E (2021) Land and heterogenous constraints nexus income diversification strategies in Ethiopia: systematic review. Agric Food Secur 10:1–14. https://doi.org/10.1186/s40066-021-00338-1
39. Tadesse T, Tesfaye B, Abera G (2020) Coffee production constraints and opportunities at major growing districts of southern Ethiopia. Cogent Food Agric 6:. https://doi.org/10.1080/23311932.2020.1741982
40. Devereux S, Teshome A (2013) From Safety Nets to Social Protection System: Options for Direct Support Beneficiaries of the Productive Safety Net Program. In: Rahmato D, Pankhurst A, van Uffelen J-G (eds) Food security, safety nets and social protection in Ethiopia. Forum for Social Studies, Addis Ababa, pp 67–110
41. Stutzer A (2004) The role of income aspirations in individual happiness. J Econ Behav Organ 54:89–109. https://doi.org/10.1016/j.jebo.2003.04.003
42. Descheemaeker K, Ronner E, Ollenburger M, et al (2016) Which Options Fit Best? Operationalizing the Socio-Ecological Niche Concept. Exp Agric 55:169–190. https://doi.org/10.1017/S001447971600048X

43. Bergau S, Loos TK, Sariyev O (2022) On- and Off-Farm Diversification and Travel Time to Markets: Linkages to Food Security in Rural Ethiopia. Eur J Dev Res 34:2543–2560. https://doi.org/10.1057/s41287-021-00475-0
44. Adem M, Tadele E, Mossie H, Ayenalem M (2018) Income diversification and food security situation in Ethiopia: A review study. Cogent Food Agric 4:1–17. https://doi.org/10.1080/23311932.2018.1513354
45. Sender J, Cramer C (2022) Desperate, deceived and disappointed: women's lives and labour in rural Ethiopia and Uganda. J Contemp African Stud 40:153–171. https://doi.org/10.1080/02589001.2021.1998393
46. Tofu DA, Haile F, Tolossa T (2023) Livelihood vulnerability and socio-economic determinants of households to climate change-induced recurrent drought in Ethiopia. GeoJournal. https://doi.org/10.1007/s10708-023-10904-8
47. Kassegn A, Endris E (2021) Review on socio-economic impacts of 'Triple Threats' of COVID-19, desert locusts, and floods in East Africa: Evidence from Ethiopia. Cogent Soc Sci 7:. https://doi.org/10.1080/23311886.2021.1885122
48. Minten B, Tamru S, Reardon T (2020) Post-harvest losses in rural-urban value chains: Evidence from Ethiopia. Food Policy 98:1–21. https://doi.org/10.1016/j.foodpol.2020.101860
49. Sobkowicz P (2018) Opinion Dynamics Model Based on Cognitive Biases of Complex Agents Pawel Sobkowicz. JASSS-THE J Artif Soc Soc Simul 21:. https://doi.org/10.19564/jasss.3867