An Agent-Based Model to Identify Migration Pathways of Refugees: The Case of Syria

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Abstract The Syrian civil war has generated a refugee crisis in the Middle East and Europe. This study draws on complex systems theory and the agent-based modelling method to simulate the movement of refugees in order to identify pathways of forced migration under the present crisis. The model generates refugees as agents and lets them leave conflict areas for a destination that they choose based on their respective characteristics and desires. The simulation outputs are compared with existing data regarding the state of forced migrations of Syrians to assess the performance of the model.

Keywords Conflict induced migration • Syrian refugees • Agent-based modeling • GIS • Migration pathways

1 Introduction

Survival and wellbeing are two important characteristics of human nature. As witnessed through history with the repeated population displacements [1, 2], people who find their social conditions dissatisfactory will often migrate to places that promise better possibilities for improvement; for example, peace and wealth compared to the violence and despair that characterize their home countries. The reasons for migration vary from economic, political and security causes, to natural or anthropogenic disasters. Nevertheless the hope is always the same, to find a safe and better place to live and prosper [1]. This is also the case for many Syrians who have faced insecurity and despair brought on by a civil war that been going on for several years now [3–6].

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A multitude of armed groups, which form an intricate web of alliances characterised by varied sets of commonalities and contradictions, add a layer of complexity to the situation. In addition, global and regional powers are involved in the conflict sometimes fighting among themselves to pursue opposite objectives [6]. In that context, it is understandable that much of the population would like to flee the region, triggering the beginning of a great migration. To better understand the dynamics behind migration, this paper presents a model that simulates the pathways the migrants use to flee their home country.

This study uses a dynamic approach to model the decision steps of the migrants, namely, the decision to leave, choices of destination and pathway as well as the decision to stay at the destination. The methodology presented here is rooted in the science of complexity and uses the agent-based modelling (ABM) approach to simulate the dynamics of migration.

The present chapter is organized in five sections. Section 2 provides, an overview on forced migration, complex systems modeling approaches and how these methods have been used to study population migration processes. Input data and the model are detailed in Sect. 3. Section 4 addresses the results, and Sect. 5 concludes the chapter.

2 Review of Literature

2.1 Conflict-Induced Displacement: Contextualizing Refugee Migration

As stated by Zetter [7], terminology is essential when addressing population displacement, and the use of incorrect terminology could have dreadful consequences on the reception and the treatment of a displaced population when reaching a safer or more desirable destination. Language misuse can be used by some countries to hide the reality of conflict-induced displacement and therefore deny the population counts of those forced to flee and find refuge [7]. By definition all refugees are migrants, however, Schmeild [8] stated that until 1990 the study of migration phenomenon was a distinct field from the study of refugee migration, which was considered to be a political phenomenon and as a consequence, was ignored by most migration literature and studies. Since then, the approach to study refugee displacement has changed and refugees' behaviour has been studied as part of migration phenomenon [9]. In general, migration refers to the permanent movement of people to a new area or country [8], while population displacement makes reference to people's movement but only within a specific time frame and generally inside a country [10, 11]. For this study, we have defined refugee migration as the event that occurs when people are forced to flee their homes as a result of a civil war. Likewise, we have adopted the legal definition of a refugee provided in 1951 by the United Nations Convention Relating to the Status of Refugees. The Convention defines a refugee as a person residing outside his or her country of nationality, who is unable or unwilling to return because of a well-founded fear of persecution on account of race, religion, nationality, membership in a political social group, or political opinion [12].

Within the literature, the study of migration is generally classified into distinct areas based on the reasons for population migration. Amongst the most studied causes for migration are economic reasons [13], climatic reasons [14–17], and conflict induced reasons [9, 11, 17]. Another important aspect considered when studying migration is the scale at which the process of migration is examined. Such as scale of examination and analysis could be national, regional or continental scale.

2.2 Complex Systems Theory

The conceptual framework of complex systems theory focuses on the many characteristic behaviours of dynamic systems such as self-organization, emergence, non-linearity, path dependence, bifurcation and sensitivity to initial conditions, amongst others [18, 19]. The modelling approaches that draw on complex systems theory, can be used to investigate how the interactions between parts can create collective behaviour within a dynamic system [20, 21] such as human migration. With the objective of modelling and examining the laws governing the behaviour of complex geographic phenomena such as forced migration, agent-based modelling (ABM) approach can be used to study the spatial patterns resulting from the complexities of human migration.

As it is the case with all complex system models, when studying human forced migration, it is important to understand the elements that characterise this phenomenon. In the case of forced migration in Syria, the movement of the population as well as the uniqueness of each individual, in addition to every aspect of the conflict creating the forced migration, are important considerations. Some research has been done in with these considerations [22, 23], but at a very local scale. The decision-making process with autonomous individuals in a bounded-rational environment, such as that of a refugee migration, is in nature heterogeneous and lends itself well to ABM as a tool for analysis [24]. Individuals represented by agents are dynamically interacting with other agents based on simple rules that will give rise to complex behaviours and patterns of displacement.

2.3 ABM and Forced Migration

The study of forced migration using ABM is still in its early stages, with statistical modelling still dominating the field [8, 17, 25, 26]. To understand the migration of Syrian refugees, most researchers have used static and statistical approaches to count the number of migrants leaving, those in transit and others arriving in each country [5, 27–29]; however, most of the studies done on forced migration have been linked to climate change [10, 16, 17, 30]. In addition, there are a few studies on conflict induced migration which have been conducted by people with an expertise in political science or sociology [11, 31], and not in geography (i.e. spatial dynamic modelling). The lack of research on migration patterns modelling can be associated with two main challenges related to the choice of decision rules and the use of empirical data [32]. Decision rules comprise the part of the model used to replicate the decision making process of a human being. Defining realistic decision rules can be difficult and that is one of the reasons why there are not many dynamic models on conflict induced migration. In this study we use a Psycho-Social and Cognitive approach [32], that is based on the planned behaviour theory [33]. Planned behaviour theory states that an individual that processes information, mediates the effects of biological and environmental factors on one's behavior. Thus, whether a behavior, for example migration, occurs or not is the result of the probability that the influence factors are compelling enough for each individual. The advantage of the Psycho-Social and Cognitive model is that it allows the inclusion of an infinite number of features to model decision making process as well as takes into account social influence and the uncertainty of life [33]. Empirical data constitutes one very important part of model development; without it, it is very difficult to parameterize and calibrate a realistic model [32]. Due to strategic reasons, valid empirical data within a conflict zone are hard to obtain, and this is why there are not many models on conflict induced migration.

When creating a migration model there are three major aspects to think about. The first is to know the moment the populations decide to leave (When). The second is to know the destination of the migrants (Where) and finally to know whether they want to stay or not at their destination. These aspects identify migration pathways.

The first aspect or the moment people decide to leave is the one that is the most studied and conceptualised [11, 14]. The choice to leave is, according to Oliver-Smith [30], not a reaction to an event, but it is due to an accumulation of factors that make people leave. Sokolowski and Banks [11] agree and add that people in risk zones choose the best options based on an analysis of circumstances, risks, and cost and benefit. That is what Klabunde and Willekens [32] present as part of planned behavior theory.

The second aspect or the choice of destination is a complex problem with multiple components; Moore and Shellman [34] investigate if refugees are more likely to relocate themselves inside or outside their country, while Schmeild [8] affirm that refugees usually go to neighboring countries with the same ethnic group and religion. In the case of Syria, refugees do not want to stay in the neighboring countries, instead they prefer to go to a country with different culture and religion (mostly in Europe) because they perceive that life in these countries is better than the ones in the Middle East [4]. Although refugees do not see all European countries on the same scale, some of them may try to enter one of the Schengen nations with the perspective to move to another if the standard of living is better [35]. In general, literature states that migrants/refugees prefer cities or countries that are politically stable, richer and safer than their departing location. It is also reported that another important aspect within the decision-making process is the capacity of absorption of migrants at each destination and the reception attitude of the host population [3–5]. Likewise, refugees will been keen to move to a rich or a more prosperous country but they will also want to move to a country in which they have family ties [36].

The third aspect is related to the degree of satisfaction with the chosen destination, and it can be divided into two different situations. The first one reports on migrant's happiness in terms of the selected place, while the second is related to the level of tolerance or rejection of refugees by the hosting community. Even though there are parts of the society that will always reject refugees [37, 38], Philips [37] argues that integration is successful when the refugees are given access to good quality accommodation available in their place of arrival. Strang and Ager [35] also suggest refugees' integration does not necessarily depend on relocating to an area with people from the same ethnic group. The three discussed aspects can be integrated into a model to mimic spatial decision making and movement of individuals forced to migrate due to conflicts such as the ongoing in Syria.

3 Data and Methods

3.1 Data

Data used in this model were acquired from various sources (Table 1). Monthly death toll data with location information was acquired via the Syrian Observatory for Human Rights [39], one of the most used data sources for the war in Syria. The extent of the datasets encompass the area of the refugee camps (Fig. 2a). From the road dataset only the primary roads and the highways were kept. From the 2004 Syrian census only those cities with more than 3000 people were considered. The model also includes indicators about destination countries [40, 41].

Table 1 Data classes and sources

Data	Source	Format
Population	Syrian census 2004, UN website, CIA world factbook	Excel
Roads, railways, cities	Open street map	Shp (point)
Airports	Open flight	Shp (point)
Political map	Thematic mapping	Shp (polygon)
Elevation	USGS global multi-resolution terrain elevation data 2010 (GMTED 2010)	Raster
Ethnic groups	GREG	Shp (polygon)
Death toll	Syrian observatory for human rights	Shp (point)
Recipient countries information	World economic forum, reporters without borders	Excel

3.2 The Model

We developed an ABM to simulate the migration of Syrian refugees, using death toll as an indicator of the severity of the conflict at each location and time. The model is comprised of human population agents who actively adapt and compare their tolerance with perceived severity of conflict and decide whether to leave their homes or not. Once they decide to depart, the agents consider a variety of conditions including their wealth, and choose a destination as well as a means of transportation. Upon arrival at destinations, the agents consider factors such as the capacity and existing population in the case of a refugee camp and decide whether to seek refuge therein. The model is iterated with 1 month time steps beginning in March 2011 and ending in December 2015.

The hybrid model allows cells to store data that is used to create, modify or influence agents [42, 43]. Other studies [16] used a ratio of agents to run the model. In our model Syrian cities create population agents at a ratio of 1 agent per 1000 people. If they decide to leave their city, population agents become migrant agents, and on arrival and settlement at their destination, the model transforms them to refugee agents. Destination options (countries, cities, and refugee camps) are given a series of indicators of attractiveness. These include: ethics, press freedom, organised crime, security, life expectancy, higher education, quality of education, quality of infrastructure, trustworthiness, public institutions and efficiency of government [49, 50]. The model also includes Syrian cities, other country cities, countries, refugee camps, airports, roads, and railways. The model implementation was made using Netlogo [44]; Fig. 1 depicts the flowchart.

3.2.1 Conflict Zones

To avoid problems (notably, lack of reliable data) of modeling the entire Syrian conflict we defined conflict zones in our model as monthly-updated, 20 km-wide areas around cities where deaths have been registered by the Syrian Observatory for Human Rights (SOHR). The higher the death toll at a zone, the more dangerous it is perceived by population agents. The deadliest recorded attack in SOHR data is assigned a danger score of 100 as reference, and danger scores of other records are calculated based on the proportion of their respective death toll to the reference. At each time step, conflict score of each conflict zone is calculated using the following formula:

$$C(t) = \frac{1}{2}[C(t-1) + D(t)]$$

$$C(t) = D(t) \quad \text{for } t = 1$$

where *C(t)* is the perceived conflict score of a zone at month *t*, and *D(t)* is the danger score of that zone at month *t*.

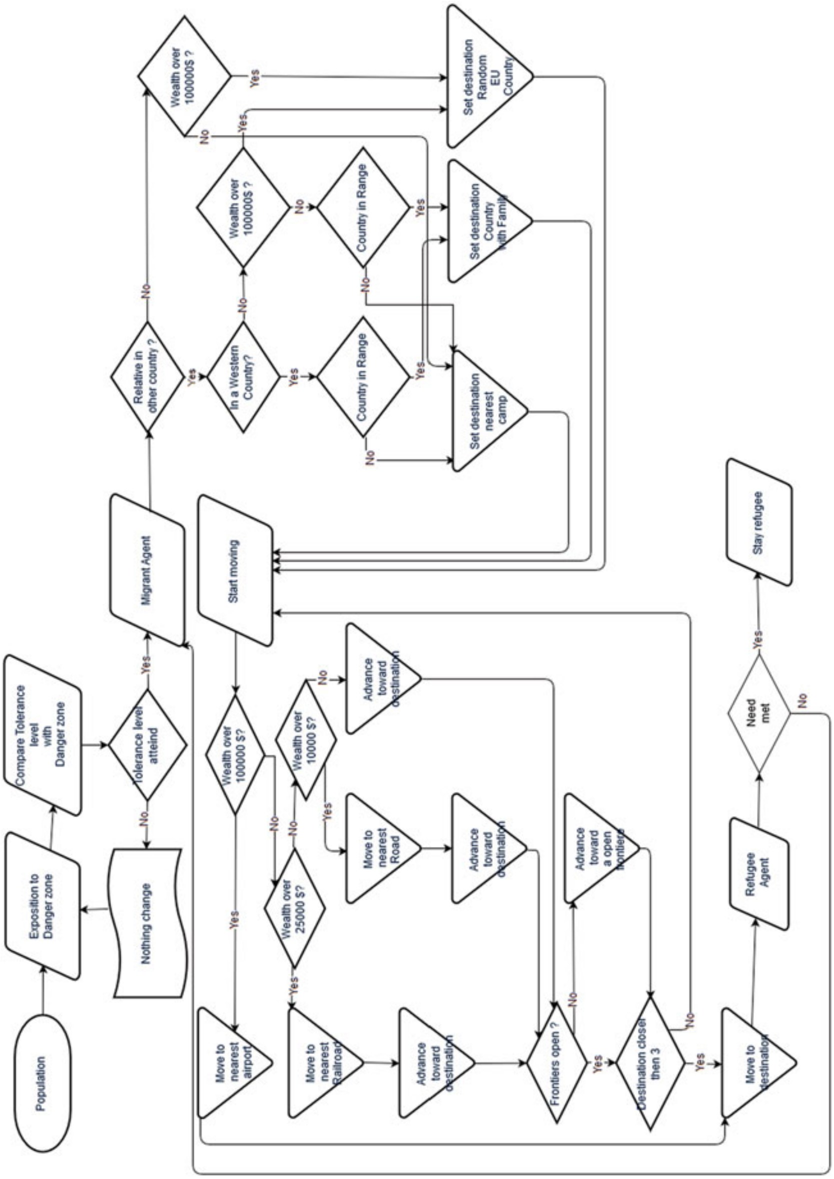

Fig. 1 Flowchart of refugee decision-making process

The inclusion of the perceived conflict score of the *previous* month (which in turn involves the effect of the month before, and so on) in the above formula enables the agents to have *memory*. The behaviour of the model will therefore be path-dependent. An implication of the above is that an agent may decide to leave even with a reduction in the danger score compared to previous time-step [45, 46].

3.2.2 Tolerance and the Decision to Leave

To assess populations' tolerance to conflict, a series of variables are associated to each agent [14]. Those include religion, ethnicity, wealth, age, sex, and familial status, the combination of which serves to determine the likelihood of an agent to leave [10, 47, 48]. In this study, due to unavailability of data, these parameters were randomly assigned. The model also considers a cumulative stress factor that reduces tolerance levels as the conflict continues. The decision rule for the first part of the model is based on a simple comparison: if the perceived severity of conflict exceeds tolerance, the population agent decides to leave, and becomes a migrant agent.

3.2.3 Destination Choice

Upon creation, migrant agents choose their destinations based on comparisons of their preferences with qualities of options available given their conditions. For example, a family member abroad could provide shelter and as such influences the choice of the migrant agent [36, 47, 49]. Moreover, wealthier migrants, can choose better means of transportation [49] and consider longer ranges. If no destinations exists for the expected criteria, the migrant agent chooses the nearest refugee camp.

3.2.4 Migration

Migrant agents choose a means of transportation depending on their wealth. On their journey, agents avoid cells with high danger scores and—especially for walking agents of very young and very old ages—cells with high slopes. Each migrant has a health score, which deteriorates with time and also in danger zones. Agents who lose all their health score, die. These features are to simulate the hardship of the migrants' journey [5, 6].

3.2.5 Arrival

Upon arrival at its destination, a migrant agent chooses whether to stay there and become a refugee agent. Overcrowding is a factor influencing such choice. Other important factors include infrastructure, sanitation and security [50, 51].

3.3 Model Parametrization

A challenge in the development of the model was the unavailability of data to set values of numerous influential parameters. We addressed this challenge by using information from relevant literature, particularly to identify parameters of highest importance, extract ranges of variation, and obtain an ordinal basis for categorizing and prioritizing levels of parameters for which a value is not available.

We acknowledge that the decision to leave is not a sudden event but the result of accumulation of pertinent factors [30, 32]. In this case, religion and ethnicity parameters were adjusted so as to make agents more tolerant when they are in regions of their own ethnicity [8]. Moreover, literature highlights that older people have more difficulty in the journey, and that they are more likely to stay in their home town longer [47, 52]. Accordingly, values of age parameters in the model were adjusted such that agents of higher age, choose departure later than others. Also, males generally have a better experience during the journey [53], therefore, the gender weight parameter is adjusted to generate more male migrants. Finally, literature notes that a single agent will be better suited to move as it is easier to travel alone than with a group [54], and that has been used as the basis for adjustment of age parameter of the model.

4 Results

4.1 Model Output

Figure 2b shows snapshots of migrant agent concentration at five temporal points. It is noticeable that the concentration of refugees in Jordan is greater than the in Turkey. Moreover, populations of Homs and Hama have fled the most. Refugee agents prefer camps far from danger zones. If we look at the Latakia region which is a regime stronghold we see a surge in migrants in that region between March and December 2015 which corresponds to the time where Russia first intervened [55].

Figure 3 shows migration pathways. We can see that a large number of migrants have fled the regions of Homs and Damascus. However this is not the case for the region of Aleppo. This can be explained by the danger level. Since Aleppo was near constant state of siege from the beginning of the conflict the danger level across this area is always high, which can refrain the migrant agents from moving. This represents the reality of many Syrians being trapped in their city or village, unable to flee due to the surrounding battle.

We can note many movements from Syria to Iraq. These could correspond to Kurd migrants and refugees fleeing northern Syria to safer zones in Iraq's Kurdistan. It is also observed that a lot of agents choose to move toward Jordan. We can also see some migrant movement from the Der-el-Zor region towards the Ambar Camp.

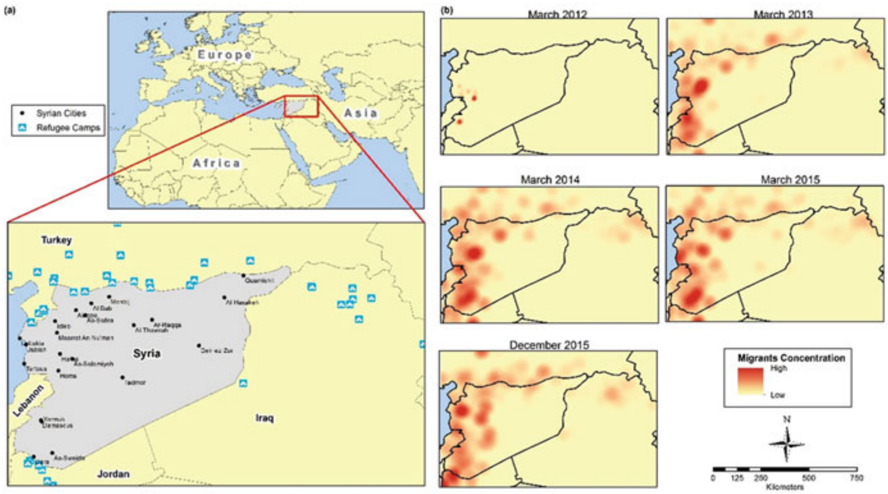

Fig. 2 (**a**) Study area and refugee camps; (**b**) Simulated migration heat map

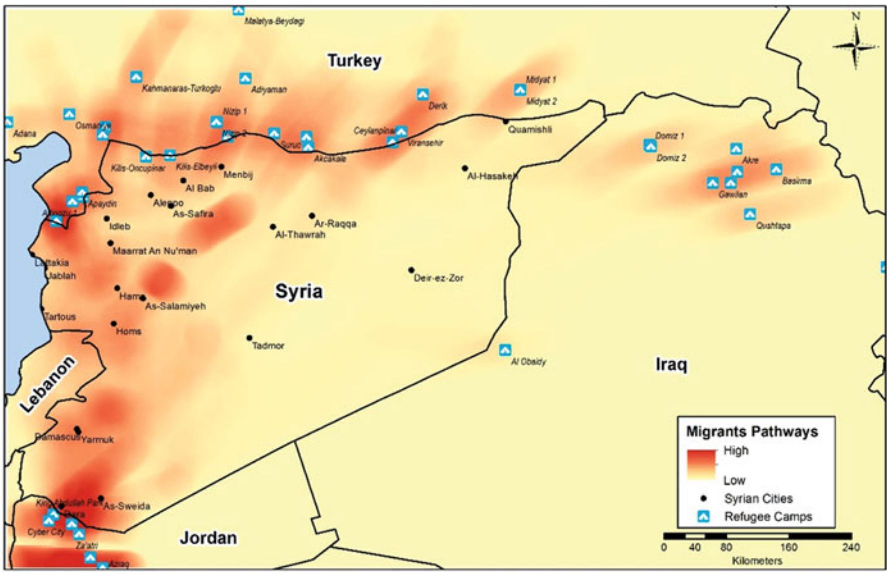

Fig. 3 Simulated pathways of Syrian migrants

4.2 Model Testing and Validation

Our model uses data on location, month, and number of deaths to simulate the consequent refugee flows. Due to unavailability of much of other data, the model cannot exactly replicate the real world. However, assuming that the death toll is a

Table 2 Quantity change and allocation tests

	Quantity	Allocation				
	Proportion change-2015	Iraq	Jordan	Lebanon	Turkey	Sum
UNHCR data	0.2661	0.0099	0.0442	0.0514	0.8946	1
Model output	0.3731	0.0927	0.2244	0.0003	0.6826	1
Minimum allocation agreement		0.0099	0.0442	0.0003	0.6826	0.7370

pertinent variable contributing to the situation, we expect our model to be able to show effects and dynamics comparable to those of the real world in terms of flows of refugees in response to the same spatiotemporal changes in the pertinent variable.

The UNHCR provides data on the number of refugees in its camps and neighboring countries [51]. We use these data to test the model, by comparing model outputs and real data in terms of quantity and allocation of change [56] between two time frames—December 2014 and December 2015. The variables that we used for model validation and testing are the rate of change in refugees arriving at neighboring countries (for quantity accuracy measurement), and the division proportions of new refugees among neighboring countries (for allocation accuracy measurement). In other words, we argue that the model generates new refugees each year and distributes them in the neighboring countries, and we perform tests to compare such generation rate and distribution shares with reference data from UNHCR [57, 58]. Table 2 shows the results of the tests.

The model shows a higher proportion of new refugees in 2015 compared to UNHCR data. This may be due in part to lack of detailed model design data, and to some extent to underestimation of the number of refugees in UNHCR records. As for allocations, the model shows lower proportions in Iraq and Lebanon, and higher in Jordan. These differences may be due to lack of data on spatial distribution of ethnicities. We used the sum of minimum agreements as a measure of allocation accuracy, ranging from 0 to 1. It must be noted that the above are results of 46th to 57th iterations (months) of the model, with death toll as the only input being updated. Moreover, while the model simulates one cause for migration of refugees, the observed data—which is the reference for testing the model—is aggregated and includes consequences of other possible causes as well.

5 Conclusion

We developed an agent-based model of violence induced migration. By using a simple variable—death toll—to simulate conflict zones, we built a model to generate migration patterns of refugees despite lack of reliable information on the details of the political and humanitarian conflict. Visual inspection of model outputs and comparison with observed data enabled us to better understand the model's capabilities and limits.

The model presented in this chapter is based on the idea that occurrence of violence at a location can cause refugee migration. Census data was used as input for spatial distribution of population. A highlight of the model design is the definition of conflict zones around locations of violence. Model testing was based on aggregate reported sums of refugees in neighbouring countries. The above aspects could also be considered for improvement and extension of future work. Regarding theory, violence-induced migration literature could suggest additional causes and mechanisms. As an example of improvement of inputs, socio-economic data with spatial distribution could, if available, replace some model assumptions. To improve the design, new models could be developed with different sizes of conflict zones, and compared to find the most realistic and reasonable amongst them. The outputs of our model could serve as information tool for humanitarian agencies in order to quickly prepare to receive refugees in cases of forced migrations, specifically in the case of the Syrian civil war. Future efforts could be made into finding reference data and developing tests that are more closely related to the model and that will help in its validation.

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References

1. Heather PJ (2016) Refugees and the Roman empire. J Refug Stud 30(2):220–242
2. Carling J (2015) Humanitarian crises and migration: causes, consequences and responses. J Refug Stud 28:138–140
3. Fargues P, Fandrich C (2012) Migration after the Arab Spring. MPC Research Report
4. Fargues P (2014) Europe must take on its share of the Syrian refugee burden, but how? Policy briefs, pp. 1–5
5. Fargues P, Fandrich C (2012) The European response to the Syrian refugee crisis–What next? European University Institute, p. 35
6. Kinninmont J (2014) The Syria conflict and the geopolitics of the region. IEMed Mediterranean Yearbook
7. Zetter R (2007) More labels, fewer refugees: remaking the refugee label in an era of globalization. J Refug Stud 20:172–192
8. Schmeild S (1997) Exploring the causes of forced migration: a pooled time-series analysis, 1971–1990. Soc Sci Q 78(2):284–308
9. Milner J (2014) Introduction: understanding global refugee policy. J Refug Stud 27:477–494
10. Oliver-Smith A (2009) Nature, society, and population displacement: Toward an understanding of environmental migration and social vulnerability. InterSecTions No. 8. Institute for Environment and Human Security (UNU-EHS), Bonn.
11. Sokolowski JA, Banks CM (2014) A methodology for environment and agent development to model population displacement. In: Proceedings of the 2014 symposium on agent directed simulation. pp. 3:1–3:11
12. Jackson IC (1991) The 1951 convention relating to the status of refugees: a universal basis for protection. Int J Refug Law 3:403–413
13. Makowsky M, Tavares J, Makany T, Meier P (2006) An agent-based model of crisis-driven migration. In: Proceedings of the Complex Systems Summer School, New Mexico

14. Smith C, Wood S, Kniveton D (2010, December) Agent based modelling of migration decision-making. In Proceedings of the European workshop on multi-agent systems (EUMAS-2010)
15. Kniveton D, Smith C, Wood S (2011) Agent-based model simulations of future changes in migration flows for Burkina Faso. Glob Environ Chang 21:S34–S40
16. Hassani-Mahmooei B, Parris BW (2012) Climate change and internal migration patterns in Bangladesh: an agent-based model. Environ Dev Econ 17:763–780
17. Rahman ABMZ (2009) Climate change, migration and conflict in Bangladesh: a view from the ground. IOP Conf Ser Earth Environ Sci 6:562003
18. Tang W (2008) Simulating complex adaptive geographic systems: a geographically aware intelligent agent approach. Cartogr Geogr Inf Sci 35:239–263
19. Manson SM (2001) Simplifying complexity: a review of complexity theory. Geoforum 32:405–414
20. Haken H, Mikhailov A (eds) (2012) Interdisciplinary approaches to nonlinear complex systems. Spinger-Verlag, New York, NY
21. Mainzer K (2007) Thinking in complexity: the computational dynamics of matter, mind, and mankind. Springer, New York, NY
22. Sprock T, McGinnis LF (2014) Modeling population displacement in the Syrian city of Aleppo. In: Proceedings of the 2014 Winter Simulation Conference, pp. 252–263
23. Collins AJ, Frydenlund E (2016) Agent-based modeling and strategic group formation: a refugee case study. In: Proceedings of 2016 Winter Simulation Conference, pp. 1289–1300
24. Epstein JM (2007) Generative social science: studies in agent-based computational modeling. Princeton University Press, New Jersey
25. Pellegrini PA, Fotheringham AS (2002) Modelling spatial choice: a review and synthesis in a migration context. Prog Hum Geogr 26:487–510
26. Henry S, Boyle P, Lambin EF (2003) Modelling inter-provincial migration in Burkina Faso, West Africa: the role of socio-demographic and environmental factors. Appl Geogr 23: 115–136
27. Yıldırım S, Yurtdaş GT (2016) Social construction of Syrian refugees in daily speech in Turkey: interpretative repertoires and social media. Middle East Journal Refugee Studies 1: 103–122
28. Taylor JE, Filipski MJ, Alloush M, Gupta A, Irvin R, Valdes R (2016) Economic impact of refugees. PNAS 113(27):1–5
29. Elizabeth B, Dunn C (2016) Refugee protection and resettlement problems. Science 352(6287):772–773
30. Oliver-Smith A (2012) Debating environmental migration: society, nature and population displacement in climate change. J Int Dev 24:1058–1070
31. Milner J (2014) Can global refugee policy leverage durable solutions? Lessons from Tanzania's naturalization of Burundian refugees. J Refug Stud 27:553–573
32. Klabunde A, Willekens F (2016) Decision-making in agent-based models of migration: state of the art and challenges. Eur J Popul 32:73–97
33. Ajzen I (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50:179–211
34. Moore WH, Shellman SM (2006) Refugee or internally displaced person?: to where should one flee? Comp Polit Stud 39:599–622
35. Strang A, Ager A (2010) Refugee integration: emerging trends and remaining agendas. J Refug Stud 23:589–607
36. Charteland G (2008) A quest for family protection: the fragmented social organisation of transnational Iraqi migration. In: Academy B (ed) Displacement and dispossession: force migration in africa and the Middle East, p 16
37. Phillips D (2010) Minority ethnic segregation, integration and citizenship: a european perspective. J Ethn Migr Stud 36:209–225
38. Awad I (2014) Population movements in the aftermath of the Arab awakening: the Syrian refugee crisis between regional factors and state interest, pp 24–39
39. Syrian Observatory for Human Rights. http://www.syriahr.com/en/
40. Schwab K (2012) World E.F.: the global competitiveness report 2012–2013, Geneva

41. World press freedom index (2016) Reporters Without Borders. https://rsf.org/en/ranking/2016
42. Gulden T, Harrison J, Crooks A (2011) Modeling cities and displacement through an agent-based spatial interaction model. In: The Computational Social Science Society of America Conference
43. Chen SH, Jakeman AJ, Norton JP (2008) Artificial intelligence techniques: an introduction to their use for modelling environmental systems. Math Comput Simul 78:379–400
44. Wilensky U (1999) NetLogo. https://ccl.northwestern.edu/netlogo/
45. Brown DG, Page S, Riolo R, Zellner M, Rand W (2005) Path dependence and the validation of agent-based spatial models of land use. Int J Geogr Inf Sci 19:153–174
46. O'Sullivan D (2004) Complexity science and human geography. Trans Inst Br Geogr 29: 282–295
47. Stefanovic D, Loizides N, Parsons S (2014) Home is where the heart is? Forced migration and voluntary return in Turkey's Kurdish regions. J Refug Stud 28:feu029
48. Melander E, Öberg M (2007) The threat of violence and forced migration: geographical scope trumps intensity of fighting. Civ Wars 9:156–173
49. Adhikari P (2012) The plight of the forgotten ones: civil war and forced migration. Int Stud Q 56:590–606
50. Melander E, Öberg M (2006) Time to go? Duration dependence in forced migration. Int Interact 32:129–152
51. Willekens F (2013) Agent-based modeling of international migration. In: Research plan for independent research group. Max Planck Institute for Demographic Research, Rostock, pp 1–19
52. Webber SC, Porter MM, Menec VH (2010) Mobility in older adults: a comprehensive framework. Gerontologist 50:443–450
53. de Haas H, van Rooij A (2010) Migration as emancipation? The impact of internal and international migration on the position of women left behind in rural Morocco. Oxf Dev Stud 38:43–62
54. Willekens F, Massey D, Raymer J, Beauchemin C (2016) International migration under the microscope. Science 352(80):897–899
55. Quinn B (2016) Russia's military action in Syria–timeline. The Guardian. https://www.theguardian.com/world/2016/mar/14/russias-military-action-in-syria-timeline
56. Pontius RG, Millones M, Gilmore R (2011) Death to kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment. Int J Remote Sens 32:4407–4429
57. United Nations High Commissioner for Refugees (2016) Global Trends: Forced displacement in 2015. http://www.unhcr.org/576408cd7.pdf
58. United Nations High Commissioner for Refugees (2017) UNHCR Syria regional refugee response. http://data.unhcr.org/syrianrefugees/regional.php