Table 1
Summary of relationship between observed and final distances (km) moved by pastoralists for the two study locations during the drought and post drought phases.

	Location					
	Dida Hara			*Web*		
Atrribute	r^2	***P-value***	***Standard error (_)***	r^2	***P-value***	***Standard error (_)***
Distance Moved Drought	0.960	<0.0001	41.650	0.977	<0.0001	38.368
Post-drought	0.955	*ns*	34.197	0.927	<0.0001	51.100

Movement patterns showed seasonal marked differentiation between the drought and post drought periods. (see Fig. 6). The average distance moved was 206 km in the drought period and 129 km after the drought.

There was a significant ($p< 0.0001$, $n= 40$, $SE= 18.70$) difference in the distance traveled during these two seasons. The pastoralists expanded the range for their foraging activity, measured as the distance from the initial location to the destination, during the drought in comparison to post drought with a mean distance of 206 km in the drought period and 129 km post-drought (Fig. 6). This represents a mean difference between the seasons of 77 km and on average, a 60% increase distance gained during the drought period.

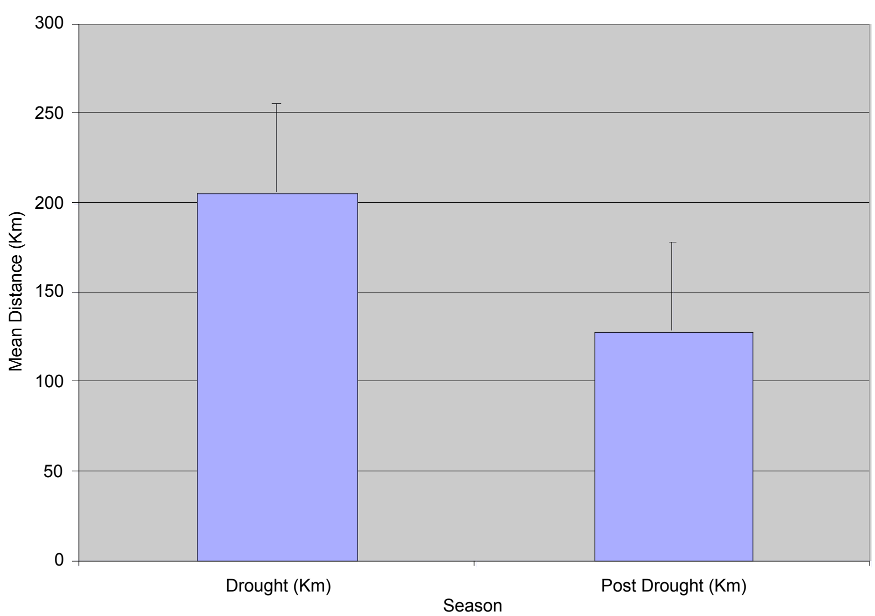

Fig. 6. Comparison of predicted mean distances (km) traveled by pastoralists during drought and post-drought seasons in the Borana lowland study area. The distance moved during drought were significantly higher than post-drought.

Discussion of findings and conclusions

The goal of this research was to develop an agent based model of pastoralist mobility on the rangelands of East Africa. Based on the agreement with observed studies in the region, the model was deemed a successful, first-generation model that mimicked several qualitative and quantitative aspects of known pastoral mobility patterns. The model was able to emulate the utilization of highly heterogeneous landscapes by pastoralists, differentiations in landscape utilization and mobility brought about by variations in seasons' forage availability (quantity), accessibility to water, rights of usage by different ethnic communities, terrain aspects among other factors.

We believe the model is potentially superior to other models of landscape use in the rangelands due to its flexibility and ability to incorporate true non-linear form of individual behavior due to its agent based formulation. Not only were we able to naturally describe the system under investigation; the model also captured movement activities which was a more natural way of describing the system than would a process based system. This system is also quite flexible, allowing addition/removal of agents to this model. ABM structure provides a natural framework for tuning the complexity of the pastoralist agents in the model, their behavior, degree of rationality, ability to learn and evolve, and rules of interactions. We also have the ability to change levels of description and aggregation within the model. Even though we have completed several simulations for this model, it still is a prototype proof of concept whose evaluation is continuing.

The PLMMO model fulfilled the Caswell (1976) criteria in that we believe it is both the best available model of pastoralist mobility behavior in the study area as yet and it best replicates many of the broad patterns exhibited by pastoralist on the ground. The scenario runs we performed on PLMMO matched known concepts about distribution of pastoralists in the arid rangelands and duplicated many of the patterns that were identified both in the field and literature.

The distance which pastoralists graze from a water point is however not simply a factor of the water sources but may vary due a number of factors including species and class of livestock, season, vegetation types, Squires (1978), security issues, user rights on common pool resources, disease etc. However by programming simple rules into individual pastoralist agents, and using a few principal influencing factors, the prototype model used here has been able to fairly accurately capture the configuration of usage of the resources on the landscape as influenced by season.

The modeling framework presented here furthermore permits examination of a broad range of hypotheses relating to rangeland social-ecological systems. The preliminary results from this study demonstrate the ability of the model structure to incorporate processes characteristic of complex adaptive systems, that are central to determining the dynamics of rangelands. We contend that the ABM model presented here provides a much more natural description of a system; and is most natural for describing and simulating a system composed of ‘‘behavioral’’ entities. We feel that PLMMO offers a more suitable approach to modeling pastoral movement and more flexible than existing models that try to explain foraging behavior in terms of habitat suitability alone. Simulation of foraging activity in African rangelands should take into account pastoralists behavioral patterns and rules, incorporate these into a model and then observe the subsequent emergent patterns and impacts. Even without full incorporation and complete knowledge of all the factors that influence pastoralist movement, initial PLMMO outputs provided here compare very well to data collected in the field. In addition, the output and predictions appear to be reasonable representations of real-world decision making patterns of pastoralists. The outcomes of the model are in tandem with what is known about the heterogeneity of pastoral resource use and behavior of pastoralists mobility during the drought and non-drought seasons. This application therefore holds promise for future application on other landscapes. Further incorporation of known factors influencing pastoralist movement such as disease quarantine, security issues, market forces, etc. will further improve model input while telemetric field-work about direction of movement of pastoralists, and real time remote-sensing of numbers of livestock mobility involved would be valuable in improving confidence of model results. As the model is refined and expanded, more sophisticated questions about relationships between policy, learning, and ecosystem dynamics can be addressed. Furthermore, the potential exists for application of the PLMMO to other tropical rangelands.

PLMMO is the first model to use an agent based mechanism to incorporate behavior of pastoralists with respect to mobility in East Africa. PLMMO has the potential to be a useful tool for policy makers, range managers, landscape ecologists, conservation planners and others interested in understanding the impact of ecological and social environment on pastoralists’ behavior and livelihoods. With this model, a user can run a variety of ecological, policy-related and land use scenarios and investigate the impact of each on the behavior of pastoralist mobility. While we have focused here only on a few factors influencing mobility to demonstrate PLMMO’s utility, the system allows for incorporating a number of other factors and is a significant improvement on similar kinds of rangeland use models in East Africa.

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