

Participatory mapping of environmental resources: A comparison of a Tanzanian pastoral community over time

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ABSTRACT

Community geographic features change over time, and this change can be contentious. Understanding social responses to this change is important for policies related to adaptation to climate change. This paper examines the use of participatory mapping of resources, at two time points, in a Tanzanian community. The results of our mapping (May 2015) were compared to those by a report by the United Nations Food and Agriculture Organization (2009). Differences included boundaries, land use designations and accessibility. These discrepancies may reflect actual changes in resources and livelihoods over time, but also differences in researcher trust and the enabling of participants. Findings suggest that repeated participatory maps, conducted in a trusting environment, are required for long-term planning in places experiencing both climate and social change.

1. Introduction

Community assessment of land use is important for planning and allocation, especially in areas where conflict over limited resources has historically occurred or is likely to arise given current trends in climate change or changes in social structure and livelihoods. The interaction between humans and the environment, taking into account salient cultural values, is an important part of political decisions (Fagerholm and Kayhko, 2009), including land use designation and accessibility. Ultimately, the health of the community and the livelihoods of its members are dependent upon the careful and equitable management of these resources, including water, land, and built infrastructure.

In the semi-arid savannah of sub-Saharan Africa, limited rainfall ‘pulses’ during the wet season create a pattern of competition for water resources between vegetation, wildlife, livestock and human populations. While this annual process has been taking place over centuries, this pattern of competition is currently evolving as climate change alters rainfall patterns (Chesson et al., 2004). Likewise, policies in the semi-arid savannah of East Africa including the prolific designation of national wildlife parks (e.g., Infield et al., 1993), the forced settlement of pastoralists (Fratkin and Roth, 2005), and land privatization (Kisamba-Mugerwa, 1996) have led to dramatic changes in land use

designations and access among community members. Documenting resources, and access to them, in this environment may help in long-term planning for climate adaptation or to clarify ownership to land and access to other resources. Participatory mapping has proven to be a useful tool for recording the allocation and ownership of resources in communities undergoing transition (Cronkleton et al., 2010), and for establishing the best practices in adapting to climate-related risks (Reichel and Frömming, 2014).

In a recent review of studies of ecosystem services in Africa (2005–2014), approximately 33% of such studies involved participatory mapping (Wangai et al., 2016) of biodiversity and ecosystem functions which benefit human wellbeing. Most ecosystem services mapping research was conducted at a regional scale. At this scale, two studies in Tanzania were included (Fisher et al., 2010; Swetnam et al., 2011). These studies focused on the economic aspects of ecosystem services, including payment for services and trends in socioeconomic drivers of ecosystem change with varying scenarios into the future. Only two (12%) mapping studies were conducted at a local scale, which is the most useful scale for direct local decision-making (Wangai et al., 2016). One of these studies was conducted in South Africa (Petz et al., 2014) and one in Tanzania (Fagerholm et al., 2012). Most relevant to the current research, Fagerholm et al. (2012) used local stakeholders as

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key informants to map and then rank the value of various local resources. They found that landscape services related to food (agriculture and livestock) were the most commonly mapped and highly valued resources. Interestingly, however, evaluation of water resources, as part of the landscape services important for livelihoods and wellbeing, was absent from this study. The authors also found scattered patterns of resources usage which led to pressures and conflicts.

Although participatory mapping may reveal tensions between groups regarding access to resources, a systematic evaluation of participatory mapping suggested that the mapping process, itself, does not significantly increase conflict (Reyes-García et al., 2012). A pre-existing conflict, however, may continue in spite of community mapping efforts. Shared land ownership, adjacent land, privatization or new designated uses of land are a few instances where conflict may arise within a community, requiring cooperation to ensure that resources are managed equitably and sustainably and all voices are equally heard (Schelhas et al., 2002). While participatory mapping has been highlighted as an effective tool for sharing community knowledge of resources, effectively planning resource management (Cronkleton et al., 2010), mediating conflict and empowering community members (Cronkleton et al., 2010; Fagerholm and Kayhko, 2009; Reichel and Frömming, 2014), the actors involved in the process of participatory mapping can significantly influence results (Chambers, 2006). However, the integration of participatory mapping and GIS techniques has proven to be a promising avenue for improving community representation and land use planning (Hessel et al., 2009) with its origins in participatory rural appraisal (Chambers, 1994).

The aims of this research were to: i) conduct participatory mapping and observe potential differences between the perceptions of male and female community members of resources in an agro-pastoralist village, Naitolia, in Monduli District, Tanzania; ii) digitally record resources identified in participatory maps using GPS to generate a spatially-accurate reference map for the community; iii) compare features, land uses and land area between our results (2015) and those of the UN Food and Agriculture Organization (2009); and iv) evaluate implications for participatory mapping as a utility by discussing possible reasons for identified differences including the intentions of external actors, goals of the community members, and the relationships or trust between parties. These two maps also present a unique opportunity to quantify land use change over time, with implications for climate change resiliency. This research uniquely contributes to the literature as it provides a repeated cross-section of community resources in a place experiencing both climate and social change. In addition, it is novel in that the identified changes are a direct, intentional result of the initial participatory mapping method itself.

2. Methods

2.1. Ethical approval

This study was approved by Michigan State University (IRB# x15-423e) and the Tanzanian Commission for Science and Technology (#2015-207-NA-2015-149).

2.2. Study site

Naitolia (also spelled Nyatolia), in Monduli District, Tanzania (see Fig. 1), is an agro-pastoralist village with a population of approximately 1800 people according to the most recent census (Census, 2012), although in our previous work, we estimated that Naitolia is comprised of approximately 300 households (Pearson et al., 2015) or 1410 residents (in 2012, Monduli District's average household size was 4.7 (Knoema, 2012)). Naitolia receives varying rainfall, averaging 650 mm annually (TANAPA, 2001). The major ethnic groups are the Waarusha and the Maasai, and their families live in dispersed *bomas* or household compounds. Other ethnic groups include Wabarbaig, Wambugwe and

Wambulu. Traditionally, in Tanzania, *bomas* were comprised of a number of Masaai households (Bekure et al., 1991) though in recent decades have become smaller and more often comprised of one household (Ikanda and Packer, 2008). Most households (~70%) are considered pastoralists in that they depend on livestock production for their livelihoods, as source of food (both meat and milk) and a store of wealth (University of Minnesota, 2010). A baseline survey of poverty in the Monduli District found 59% of rural households to be considered below the poverty level, where household consumption is below what is required to satisfied basic needs (EDI, 2005).

Drought in the area has led to a shrinking water supply and declining agricultural productivity, with concomitant food insecurity and health issues (TPP, 2008). Availability of water and reliable access to quality water are major priorities for sustainable community development and public health promotion in Naitolia, for which recent interventions have been implemented by Michigan State University's Tanzania Partnership Program (TPP). Naitolia was selected as a study site for this participatory mapping study to understand the current state of environmental resources, which have not only been threatened by a climate characterized by severe drought, but repeatedly subject to the intervention of external political agencies due to Naitolia's key location in the wildlife corridor. This village is an optimal setting to compare changes in land use over time due to: 1) the insecurity of water in the region; 2) the increasing shift from purely pastoral to agro-pastoral livelihoods; 3) the recent designation of many adjacent areas as conservation areas; and 4) the ability to compare contemporary land use changes using an existing participatory mapping exercise from 2009.

2.3. Data collection and map generation

Participatory mapping exercises were carried out in May 2015 with two separate groups at the village government office building in Naitolia. First, adult women (n = 10) participated in the mapping exercise followed by a group of adult men (n = 10). Thus, these 20 participants represented the optimal size of volunteer focus groups as established in other participatory mapping studies (Mapedza et al., 2003). The objective of working in these groups was to ensure freedom of expression, avoid gender bias in interpreting access to resources in the mapping activities, and to see whether the two groups perceive access and uses differently. These methods, particularly small, organized groups, have been established as both effective and integral for landscape visualization (Boedhihartono, 2012).

In each group, a table was placed in the center of the participants. A large sheet of paper and different colored markers were provided. Participants were instructed, first in English and then translated in Swahili, to create a map, using the markers and the paper, of the important features of Naitolia, including small features of the village and large areas, noting specific uses and which community members had access or were restricted. Participants were probed on the following: forest resources, farms, grazing land, water sources, tourism or other conservation areas and community amenities (e.g., church, school). During the map creation, notes were taken by field staff in English with assistance from Swahili translators related to disagreements or consensus on boundaries or features. This process lasted about one hour for each group. At the end, a photo of each map was taken and differences between the male- and the female-generated maps were noted.

Following participatory mapping activities, all features from both maps were visited to obtain GPS coordinates (using ArcCollector, ESRI, Redlands, CA, USA). Last, digital maps of all features were created, including both English and Swahili names [data available upon request]. Our digital participatory map was made from combining all features from the two hand-drawn maps, and was then used to compare with a prior participatory map, created in 2009 by the UN Food and Agriculture organization (UN FAO).



Fig 1. Map of Monduli District, Tanzania.

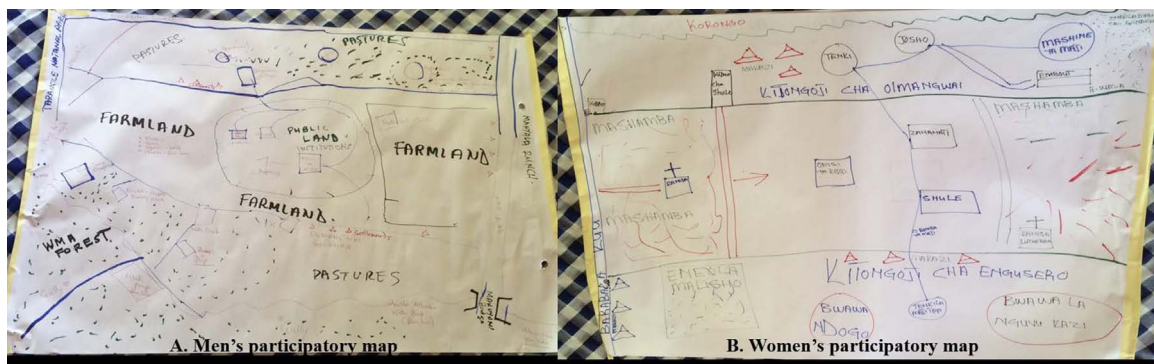


Fig. 2. A & B: Participatory mapping exercise results.

2.4. Comparison with prior participatory map (UN 2009)

From 2007–2009, a GEF/World Bank-funded project called “*Novel Forms of Livestock and Wildlife Interactions Adjacent to Protected Areas in Africa-Tanzania*” was implemented by the United Nations Food and Agriculture Organization (UN FAO), African Wildlife Foundation, International Livestock Research Institute and the Government of Tanzania in six villages, including Naitolia. The goal of the project was to address the management and conservation of resources for the promotion of community livelihood and preservation of biodiversity and to officially establish a Wildlife Management Area (WMA) adjacent to Naitolia (UN FAO, 2009).

Participatory land-use planning was implemented as part of this project. A sketch map of Naitolia indicating existing land use from this project was included in the final report (UN FAO, 2009). A copy of the UN 2009 map, digitized by the University of Minnesota’s Whole Village Project (University of Minnesota, 2010) was used for comparison in our study.

To quantify differences in land use and area, the two digital maps were imported into Photoshop CS6 software (Adobe, San Jose, CA, USA). Our map was then overlaid on the UN 2009 map by aligning an easily distinguishable feature – the *korongo*, or gully, that serves as the eastern boundary of Naitolia. The opacity of our map was set to 70% and exposure adjusted to allow for the land use and area of both maps to be visible concurrently.

This image of the combined map was then imported into Google Earth Pro (Google, Mountain View, CA, USA) and georeferenced using

both the UTM coordinates provided in the UN 2009 map and permanent, physical features such as the Tarmac road and the *korongo* visible in the satellite imagery. The polygon tool was then used to calculate and record total land area in km² for each unique land use provided in the maps. Last, the intentions of the mapping exercises, goals of the community members, and the relationships or trust between parties were assessed for both our participatory mapping exercise and for the UN 2009 exercise, through examination of their final report (UN FAO, 2009).

3. Results

The following features were drawn during our two participatory mapping exercises: boreholes (including boreholes outside of Naitolia commonly used boundaries), tap locations on tanks (both borehole and rainwater fed), hand-dug surface water ponds, the adjacent WMA land, Naitolia sub-village locations, neighboring villages, a natural gully (the *korongo*), farms, grazing areas, schools, churches, a government office, and a health dispensary (under construction) (see Fig. 2A & B). These features were then used to generate a digital map of Naitolia (see Fig. 3).

Participants had strong feelings about the locations of the boundaries of their community. This was the starting point for creating the maps in both groups and all members agreed on these boundaries. One village boundary was a natural feature (the *korongo*); one was a road; one was shared with the Randileni Wildlife Management Area (WMA) and one was shared with Mswakini Juu, a neighboring village.

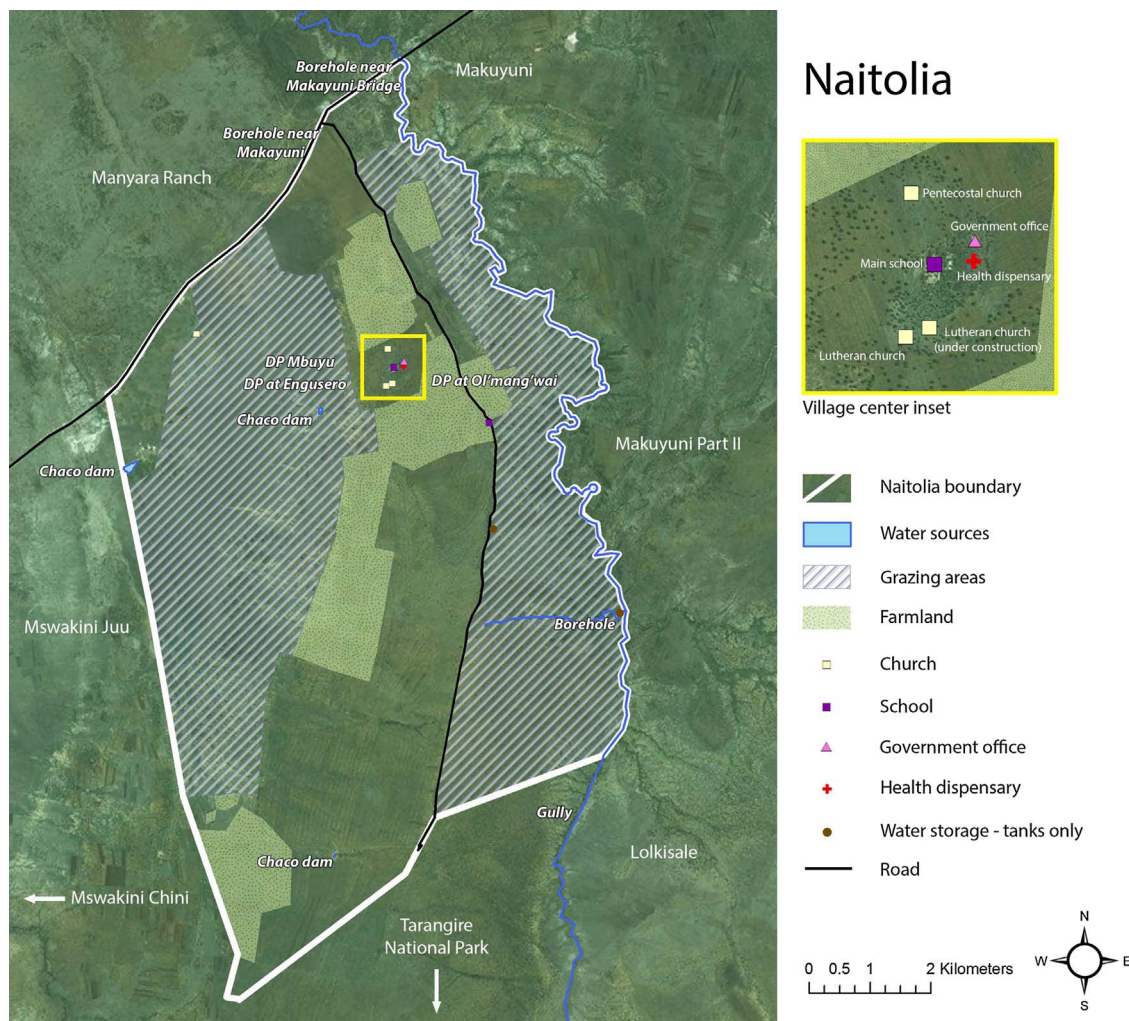


Fig. 3. Digitized map of our participatory mapping exercises (2015).

From the order of the features drawn on the maps, the level of detail and the level of consensus, it was clear that the women knew less about the location, size, and availability of pasture lands and water sources used primarily for cattle and other livestock (i.e., *chaco* dams, or traditional hand-dug pond-like earth dams that collect rainwater for agricultural and household use) than the male informants. In addition, the women were unable to describe how access to the WMA conservation area could, at times, be granted. In contrast, the men were able to provide great detail on each of these features. Water resources were a dominant feature in both group maps, including taps on tanks (both rainfed and from a borehole), stand-alone taps, hand-dug surface water sources (*chaco* dams), a natural spring in a gully (the *korongo*), and boreholes located outside the village itself.

Participants also reported that wildlife affect the entirety of the community, rather than a specific location or area of Naitolia, due to its proximity to both WMA land and several national parks (which are managed to benefit wildlife), and its inclusion in the migration corridor between parks. As a result, participants reported that wildlife-human conflict and crop damage are common.

Participants also reported the new construction of a dispensary (still under construction at the time of writing) – the only health care service of any sort in the village. Villagers currently travel approximately 20 km to the nearby town of Makuyuni to receive health care services.

3.1. Comparison with UN 2009 map

When comparing differences between our map and the UN 2009 map, we examined the features included in the map as well as land uses and land area. The features included on the UN 2009 map included: existing land use, roadways, neighboring villages and a wildlife park. In addition to the first three features, our map also included water sources, water storage, community buildings, and a distinction between farmland and land used for grazing.

We also found discordance between the maps when comparing the village boundaries. Our village boundaries did not coincide with the boundaries in the UN 2009 map, nor with the 2002 Census boundaries (though the 2012 Census may provide new boundaries, these were not yet available by the Bureau of Statistics at the time of writing). We found the village boundaries to include far less land area (95 km²), compared to the other two sources (256 km² and 237 km², respectively). The only common boundary, identified by our map and the UN 2009 map was the *korongo*. In our map, participants cited the Tarmac road as the northern boundary, where the UN 2009 map denotes additional area considered to be Naitolia. Despite its inclusion in the UN 2009 map, this land is part of Manyara Ranch Conservancy, a private ranch and conservation area purchased by the African Wildlife Fund from the Tanzanian government in 2001 (Manyara Ranch Conservancy, 2017). This was accentuated by the fact that water from Manyara Ranch, which is available year-round, can only be accessed by those in Naitolia at a cost [7]. In our map, the southern village boundary

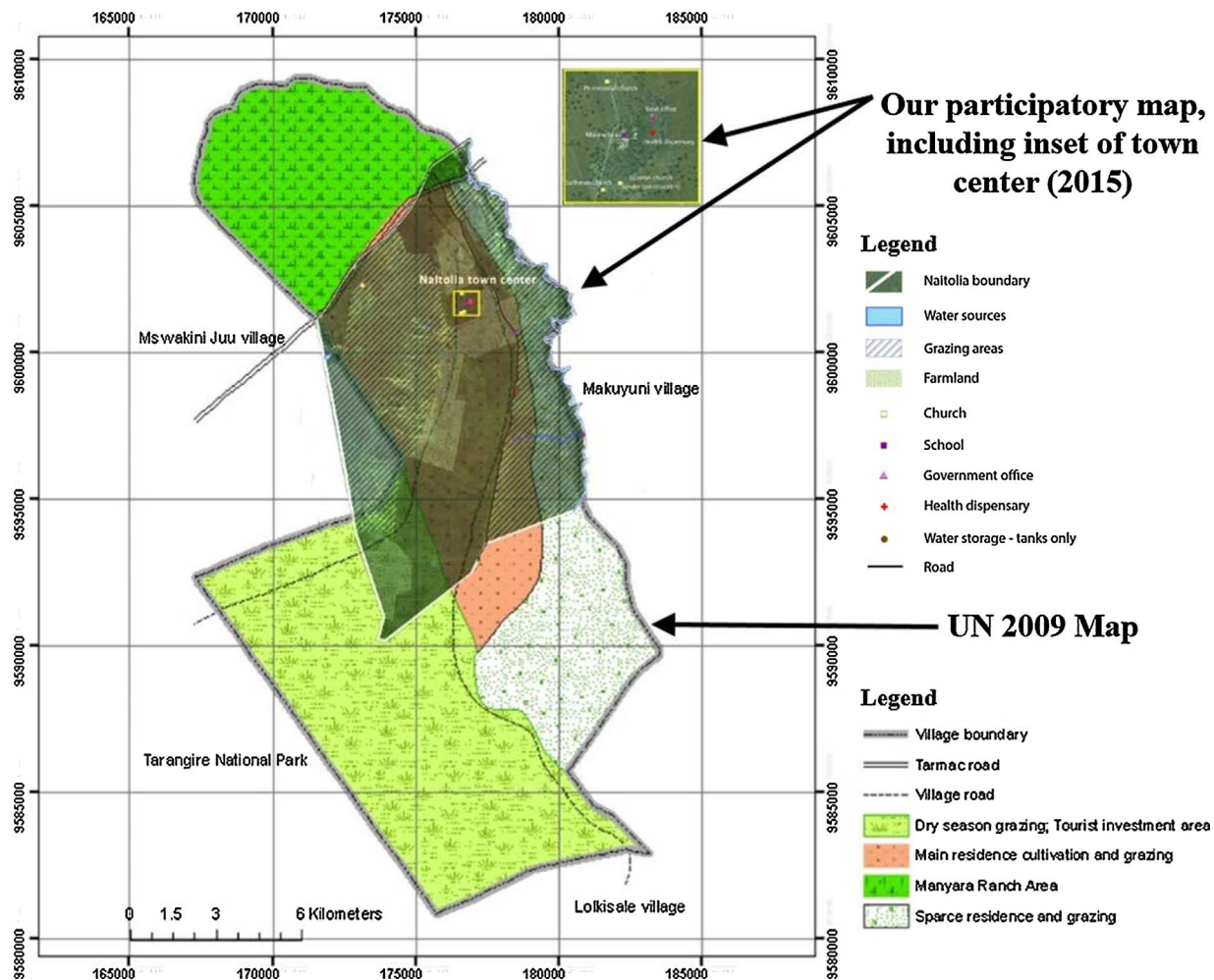


Fig. 4. Overlay of our participatory map (2015) onto the UN 2009 map.

(occupied by WMA land), was described by male participants as forested land with very limited access due to WMA regulation. In contrast, the UN 2009 map showed this region as an extended area of 'dry season grazing/tourist investment area' for Naitolia. Our map reflects the subsequent (post-UN 2009 mapping) development of the WMA land, and the related decline in both land area and available resources for Naitolia, which can be linked to ongoing challenges related to food security.

Within Naitolia, specific land uses were indicated differently between maps. Participants in our study indicated that farmland was largely restricted to sections near the center of the village and with additional farmland in the south of the village (see Fig. 3). In contrast, no areas in the UN 2009 were designated for specifically for agriculture. The UN 2009 map defined 'main residence, cultivation and grazing' as a single, central portion in the western majority of the village, while the area to the east, just beyond a bifurcated main road, was defined as sparse residence and grazing (see Fig. 4). In the UN 2009 map, no distinction was made between agriculture and grazing land uses. Lastly, the UN 2009 map does not include features such as water sources, a village center, or any of the built features within the village (eg, schools, government office, etc).

As shown in Table 1 and Fig. 4, our map determined Naitolia's total land area to be 95 km² while the UN 2009 map determined the land area to be much larger, at 256 km², a difference of 161 km². Our map indicated an area of 51 km² used for grazing, 13 km² used as farmland, and 31 km² for an unspecified use. In contrast, the UN 2009 map showed 69 km² as 'main residence cultivation and grazing', 46 km² as 'sparse residence cultivation and grazing', and no areas within the

Table 1

Comparison of land areas by usage between our map (2015) and the UN 2009 map.

Land use designation, km ²	Our map (2015)	UN 2009 map
Grazing land	51	
Farmland	13	
Unspecified & town center	31	
Main residence, cultivation & grazing		69
Sparse residence & grazing		46
Manyara Ranch		45
Dry season grazing & tourism		96
Total	95	256

village boundaries for an unspecified use. The UN 2009 map also included Manyara Ranch (45 km²) in the north and a 'dry season grazing; tourist investment area' (96 km²) in the southwest, both as part of the village of Naitolia. Only 11 km² of the latter area is included within the boundaries of Naitolia as defined in our map. The only portion of Naitolia in our map, but not in the UN 2009 map, was a 7 km² area designated for grazing along the western boundary of the village.

4. Discussion

Given the results comparing our map with the UN 2009 map, we now discuss possible reasons for the identified differences including the intentions of external actors, goals of the community members, relationships or trust between parties, and actual environmental and social changes reflected in the identified differences. First, both the

features of the UN 2009 map and the fact that its purpose included establishing a WMA, suggest that the community members were cognizant of the potential for land loss resulting from the mapping process especially following the transition of Manyara Ranch from public to private land, less than a decade earlier. In this map, every portion of the village was assigned a land use category, in contrast to our map, where participants did not specify usage for all land. These differences could be the result of the methods and instruction given during the mapping exercise, a difference in interpretation by participants, or a reflection of the trust between the varying actors and data collectors in each mapping session. For example, participants may have felt the need to assign value to the land to protect it during the UN mapping exercise. However, due to a trusted relationship between the village and the researchers involved in the 2015 map, participants may not have felt compelled to do so. Second, the privately held Manyara Ranch was no longer considered within the boundaries of Naitolia by the community, and yet it was included in the UN 2009 map. Including Manyara Ranch in the village boundary resulted in Naitolia appearing larger than in reality, and encouraging the notion that repurposed land is fully accessible to the community. These differences reflect the need for careful attention to the intentions and relationships between external and internal actors in the participatory mapping process to ensure that the community is both properly and fairly represented.

The UN FAO exercises were initially presented to Naitolia as an opportunity for community-based land and resource management. However, this participatory mapping process resulted in the loss of a large portion of land for the Randileni WMA, and ultimately without the financial compensation or structural improvements that are intended to benefit WMA member villages. Instead, this action limited access to it for grazing and water during the dry season, a vital coping strategy used by the community. The establishment of the WMA, while rooted in the conservation of biodiversity, has also exacerbated conflicts between the community and wildlife as this area is increasingly protected as a wildlife corridor. Such forest resources, located in the vicinity of villages, have been shown to be important for human well-being. Another village-level participatory mapping study in Tanzania found that forest resources, like the WMA, are places that serve multiple (> 10) and *crucial* material and non-material ecosystem needs for community members (Fagerholm et al., 2012). Overall, our findings of decreased ecosystem services (for human benefit) are echoed in almost all other ecosystem services mapping research in Africa over the past decade (Wangai et al., 2016), with some studies indicating that socioeconomic and political factors are often, in part, drivers of this decline (e.g., Swetnam et al., 2011).

Our map showed a shift in the designation of specific land for agriculture from the UN 2009 map's mixed land use of residential, agriculture and livestock. This land use shift likely indicates a similar shift in livelihoods in Naitolia. Similarly, in the Zanzibar region of Tanzania, increases in cultivation and decline in forest resources are projected by 2025 under different scenarios related to socioeconomic change trends (Swetnam et al., 2011). Larger plots of farmland today indicate more intensive dedication to agriculture, compared to the past. This is in contrast to an historical reliance primarily on livestock, with small subsistence-based agriculture near the home. The pressures of climate change, increasing water insecurity, and a shift from pure pastoralism to agro-pastoralism mean that repeated cross-sectional mapping exercises will be important for future community-based land use and planning. Importantly, in 2014, a land use plan contrary to that facilitated by the UN was developed in Naitolia. The land use plan was an idea that started at the community level, through cooperation with the Municipal Council and ultimately the Ministry of Land. This plan demarcated the area for pastures, farmland and residential land with the intention of preventing outsiders from grazing in the village.

This study has limitations. One limitation was a lack of detail about the methodology and sample for the UN 2009 map, limiting our ability to understand differences in findings. Also, land area calculations may

be slightly imprecise through two avenues. First, the process of translating a hand-drawn map to digital form may lead to possible lack of precision. Second, the process of overlaying the two maps may have caused (likely very slight) imprecision. Also, TPP has a long, trusted relationship with the community, but TPP has also provided funds for water infrastructure improvements, which may introduce bias. Our map may also be subject to limitations due to our reliance on Swahili (as opposed to Maa, the language of the Maasai people) as the language of instruction. In fact, one participant pointed this out during the participatory mapping and reminded her fellow participants to speak Swahili only. It is possible that our lack of using the local language could have influenced their interest in the activity, their level of trust in the researchers, or our interpretation of the data. Future studies could usefully include value ranking of resources and perceptions of resources, as done by Fagerholm et al. (2012). Pairing values with digital maps of resources could provide a more nuanced and locally-appropriate basis for future land use decision-making among and across communities.

5. Conclusion

This study illustrates how participatory mapping may be an invaluable tool for informing resource management decisions, and yet vitally subject to the intentions and methodology of the researchers, which may determine which groups are empowered by its implementation. By comparing our participatory mapping results to those of the UN, we identified changes in culture and livelihood reflected in land use including larger areas for agriculture. Repeating the participatory mapping process over time, with careful attention to inclusiveness and trust, is one method of monitoring both climate and social change while facilitating community planning and adaptation strategies.

Conflict of interest

The authors have no competing interests to declare.

Author's contributions

AP and RR conceptualized the study, with RR securing funding for the research and AZ securing funding for AR. AP, RR, MCL and EM conducted the data collection. AR and AP led spatial analyses and drafted the manuscript. All authors read and approved the manuscript.

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References

- Bekure, S., de Leeuw, P.N., Grandin, B., Neate, P. (Eds.), 1991. *Maasai Herding: An Analysis of the Livestock Production System of Maasai Pastoralists in Eastern Kajiado District, Kenya*. ILCA, Addis Ababa, Ethiopia.
- Boedhihartono, A.K., 2012. *Visualizing Sustainable Landscapes: Understanding and Negotiating Conservation and Development Trade-offs Using Visual Techniques*. (Retrieved from Gland, Switzerland).

- Census, 2012. Village Statistics.
- Chambers, R., 1994. The origins and practice of participatory rural appraisal. *World Dev.* 22 (7), 953–969.
- Chambers, R., 2006. Participatory mapping and geographic information systems: whose map? Who is empowered and who disempowered? Who gains and who loses? *Electron. J. Inf. Syst. Dev. Ctries.* 25.
- Chesson, P., Gebauer, R.L.E., Schwinning, S., Huntly, N., Wiegand, K., Ernest, M.S.K., Weltzin, J.F., 2004. Resource pulses, species interactions, and diversity maintenance in arid and semi-arid environments. *Oecologia* 141 (2), 236–253. <http://dx.doi.org/10.1007/s00442-004-1551-1>.
- Cronkleton, P., Albornoz, M.A., Barnes, G., Evans, K., de Jong, W., 2010. Social geomatics: participatory forest mapping to mediate resource conflict in the bolivian amazon. *Human Ecol.* 38 (1), 65–76. <http://dx.doi.org/10.1007/s10745-009-9296-4>.
- EDI, 2005. Baseline Survey on Poverty, Welfare and Services in Monduli District. (Retrieved from Bukoba: <http://edi-global.com/docs/cwiq/CWIQ%202005%20MONDULI.pdf>).
- Fagerholm, N., Kayhko, N., 2009. Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar, Tanzania. *Fennia – Int. J. Geogr.* 187 (1), 43.
- Fagerholm, N., Käyhkö, N., Ndumbaro, F., Khamis, M., 2012. Community stakeholders' knowledge in landscape assessments – mapping indicators for landscape services. *Ecol. Indic.* 18, 421–433. <http://dx.doi.org/10.1016/j.ecolind.2011.12.004>.
- Fisher, B., Kulindwa, K., Mwanyoka, I., Turner, R.K., Burgess, N.D., 2010. Common pool resource management and PES: lessons and constraints for water PES in Tanzania. *Ecol. Econ.* 69 (6), 1253–1261. <http://dx.doi.org/10.1016/j.ecolecon.2009.11.008>.
- Fratkin, E., Roth, E.A., 2005. *As Pastoralists Settle: Social, Health, and Economic Consequences of the Pastoral Sedentarization in Marsabit District, Kenya*. Springer, New York.
- Hessel, R., van den Berg, J., Kaboré, O., van Kekem, A., Verzaandvoort, S., Dipama, J.-M., Diallo, B., 2009. Linking participatory and GIS-based land use planning methods: a case study from Burkina Faso. *Land Use Policy* 26 (4), 1162–1172. <http://dx.doi.org/10.1016/j.landusepol.2009.02.008>.
- Ikanda, D., Packer, C., 2008. Ritual vs. retaliatory killing of African lions in the Mgorongoro Conservation Area, Tanzania. *Endang. Species Res.* 6, 67–74.
- Infield, M., Namara, A., Marquardt, M., 1993. Retrieved from kampala. The Socioeconomy, Natural Resource Use, and Attitudes Towards the Park of Communities Living in and Around Lake Mburo National Park: Report of a Rapid Rural Appraisal.
- Kisamba-Mugerwa, W., 1996. Individualisation of Pastoral Resources. Makerere University, Kampala.
- Knoema, 2012. Populations and Average Household Size in Tanzania. (Retrieved from <https://knoema.com/TANPOAHS2016/population-and-average-household-size-in-tanzania-2016?region=1001990-monduli-district-council>).
- Manyara Ranch Conservancy www.manyararanch.com Accessed May 2017.
- Mapedza, E., Wright, J., Fawcett, R., 2003. An investigation of land cover change in Mafungautsi Forest, Zimbabwe, using GIS and participatory mapping. *Appl. Geogr.* 23 (1), 1–21. [http://dx.doi.org/10.1016/S0143-6228\(02\)00070-X](http://dx.doi.org/10.1016/S0143-6228(02)00070-X).
- Pearson, A.L., Rzotkiewicz, A., Zwickle, A., 2015. Using remote, spatial techniques to select a random household sample in a dispersed, semi-nomadic pastoral community: utility for a longitudinal health and demographic surveillance system. *Int. J. Health Geogr.* 14 (1). <http://dx.doi.org/10.1186/s12942-015-0026-4>.
- Petz, K., Glenday, J., Alkemade, R., 2014. Land management implications for ecosystem services in a South African rangeland. *Ecol. Indic.* 45, 692–703. <http://dx.doi.org/10.1016/j.ecolind.2014.05.023>.
- Reichel, C., Frömming, U.U., 2014. Participatory mapping of local disaster risk reduction knowledge: an example from Switzerland. *Int. J. Dis. Risk Sci.* 5 (1), 41–54. <http://dx.doi.org/10.1007/s13753-014-0013-6>.
- Reyes-García, V., Orta-Martínez, M., Guezab, M., Luz, A.C., Paneque-Gálvez, J., Macía, M.J., Team, T.B.S., 2012. Does participatory mapping increase conflicts? A randomized evaluation in the Bolivian Amazon. *Appl. Geogr.* 34, 650. <http://dx.doi.org/10.1016/j.apgeog.2012.04.007>.
- Schelhas, J., Sherman, R.E., Fahey, T.J., Lassoie, J.P., 2002. Linking community and national park development: a case from the Dominican Republic. *Nat. Resour. Forum* 26 (2), 140–149. <http://dx.doi.org/10.1111/1477-8947.00014>.
- Swetnam, R.D., Fisher, B., Mbilinyi, B.P., Munishi, P.K., Willcock, S., Ricketts, T., Lewis, S.L., 2011. Mapping socio-economic scenarios of land cover change: a GIS method to enable ecosystem service modelling. *J. Environ. Manage.* 92 (3), 563–574. <http://dx.doi.org/10.1016/j.jenvman.2010.09.007>.
- TANAPA, 2001. Tarangire National Park General Management Plan/Environmental Impact Assessment. Tarangire National Park, Tanzania.
- UN FAO, 2009. Mapping Our Community's Future: Why and How to Practice participatory Land-Use Planning. Food and Agriculture Organization, Rome, Italy.
- University of Minnesota, 2010. Whole Village Project Survey in Naitolia Village in Monduli District Tanzania. University of Minnesota, Minneapolis.
- Wangai, P.W., Burkhard, B., Müller, F., 2016. A review of studies on ecosystem services in Africa. *Int. J. Sustain. Built Environ.* 5 (2), 225–245. <http://dx.doi.org/10.1016/j.ijsbe.2016.08.005>.