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Characterizing problematic plants in the drylands of Tanzania

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Abstract

This pilot study focused on problematic plant species in Tanzania's Northern Drylands. The objectives were to 1) define problematic plants according to local, non-Western descriptors, 2) identify region-specific problematic species, and 3) characterize impacts those species have on indigenous Maasai livelihoods and the environment. Ecological disturbances, such as land-use and climate change, can have pronounced impacts on vegetation, including the appearance and potential spread of problematic plants. Western classifications of problematic plants include invasive, poisonous, and noxious qualities. Local identification of such species, however, may differ from Western conceptualizations. The implications of problematic species on Maasai social-ecological systems, including pastoral herding, cultivation, and the ecosystem, has not been scientifically investigated. Therefore, seven focus groups were conducted in two villages of Simanjiro District, Tanzania to develop a comprehensive list of problematic plant species, an assessment of their natural history, and problematic traits as defined by traditional ecological knowledge. The groups were gender-based to promote inclusive contributions from men and women and incorporated young adults to senior elders to honor collective wisdom among villagers. All species were individually ranked according to their problematic traits' significance through participatory exercises, and species of paramount concern were further characterized. Results show a disparity between Western (academic) and non-Western (Maasai traditional) conceptualizations of problematic traits. Western definitions tend to be eco-centric, focusing on environmental harm, whereas Maasai definitions pertain more to the detriment of people and their livelihoods. Additionally, using qualitative data analyses, salience scores were calculated by comparing the frequency and average rank of each species. Four species were identified (in Maasai language) as the most problematic: *alairahirah*, *almererwaki*, *orkiyapore*, and *otelemet*. Identifying the species by their scientific names is in progress. Future results could help with classification and mitigation of the spread and disturbance of problematic plants, improving pastoral livelihoods in Northern Tanzania.

Keywords: problematic plants, social-ecological systems, Tanzania drylands

1. Introduction

1.1. East African Dryland Social-Ecological Systems

The focal point of this research project is the Simanjiro District, a dryland region of Northern Tanzania. Drylands are areas that receive very limited and punctual precipitation. Average annual rain falls between 100-500 mm and 500-1000 mm in arid and semi-arid zones, respectively. In East Africa, these rains fall in a bimodal pattern with a short rainy season occurring from October through November and a longer rainy season from late February through May[10]. Stochastic weather patterns are the driving force of dryland ecosystems because they determine the most limiting factor of the system: water. Because these systems are reliant on unpredictable factors such as precipitation, they function non-equilibrially; the system is constantly adjusting to new climatic states[9]. With the region's extreme flooding and drought events increasing in frequency and intensity due to climate change, it could equate to greater fluctuations in the ecosystem's structure, function, and services[20].

To survive in this environment, one group of indigenous peoples, called Maasai, have discovered various ways to cope with the climatic fluctuations as a form of investment diversification. Agro-pastoralism, the semi-nomadic lifestyle of managing livestock and supplementing with cultivation, is the primary livelihood of Maasai. Pastoralists herd their livestock, which can encompass any combination of cattle, camel, donkeys, sheep, and goats. They rotate between productive grass- and shrublands while allowing others to lie fallow for regrowth. Livestock provide many uses for Maasai: sustenance including milk, meat, and occasionally blood; social exchange for trade, gifts, and collateral; and transportation. To supplement their diet, Maasai keep family gardens and small farms, called *shambas*, which primarily produce maize and beans[17]. Both livestock production and cultivation yields depend on proper resource management and environmental conditions that control water and forage availability[27].

This sustained social-ecological interaction is a result of traditional (indigenous) ecological knowledge (TEK). TEK is information that pertains to the natural world that is transmitted to each successive generation, typically through practice and oral communication[25]. It is the foundation of how human communities choose to interact with their natural environment as well as their capacity to adapt to environmental changes and disturbances[26]. Maasai have developed TEK over centuries on the East African drylands. For example, herders use woody and herbaceous plant species as bioindicators of pastures' grazing capacity[18]. The use of TEK in ecological research can also offer information that is overlooked by other systematic information-gathering methods traditionally used in academia[25].

1.2. Problematic Plants

Drylands typically follow a consistent vegetative framework: dominant herbaceous species (grasses and sedges), scattered forbs, and few woody species[22]. As stated above, climate change can be detrimental to dryland systems because it changes the ecological makeup of the system. In the dryland of East Africa, climate change leads to reduction of annual rainfall and increases extreme weather events[20]. Flooding and drought are large-scale ecological disturbances with the capacity to affect the community structure and dynamics and thus modify the ecological state of the system[4]. These perturbations cause renewed lands and resources to become available, allowing new and surviving species to recolonize the disturbed area, fill empty niches, and change the land cover[7]. Advantageous and competitive species utilize these opportunities to spread, resulting in systemic imbalance. Oftentimes these species can be problematic by posing harm to the social-ecological systems in which they are a part of. Problematic plant can be defined by the threat they pose on an ecosystem through noxious, invasive, unusable, and nuisance qualities[6].

One notable type of problematic plant is non-native invasive alien species (IAS), or anthropogenically-introduced species that cause disturbances to newly inhabited foreign ecosystems[16]. Globally, IAS cost an annual average of USD 1.4 trillion and are the second leading cause of biodiversity loss. The increase of IAS has paralleled global population growth as a result of increased travel, transportation, and globalization[21]. Dispersion of alien species can be accidental (tourism or travel) or intentional (ornamental purposes, wood or fiber productions, crop use, and habitat improvement)[8]. IAS have the ability to spread due to decreased natural predators, reduced competition, or increased resource availability[5]. If IAS are relatively more successful, they can outcompete native species for essential resources, further destabilizing ecosystem function.

Problematic species are often accompanied by an array of socioeconomic impacts[5]. They can outcompete local crops for resources causing detriment to yield, profit, and local food security. In drylands, changes in water such as infiltration, runoff, evapotranspiration, and groundwater access can magnify these impacts. They can prove poisonous for humans and animals. These situations of disrupted ecosystem services equate to large impacts on land-use opportunities for civilizations that depend on them, such as the Maasai.

1.3. Pilot Study

Several areas of knowledge are lacking in reference to problematic plant species research in Tanzania. First, there is no clear or widely accepted non-Western definition of problematic plant species. In the academic world, scientists typically consider only invasive or alien species to be threatening. However, many plant-caused problems may be overlooked as a result of this predetermined definition. Second, unlike many of its neighboring countries, there is scarce published research that has been done in Tanzania, which is in part due to the difficulty of acquiring international research permits. Third, no research studies thus far have measured the impacts that problematic species have on land-use opportunities and livelihoods of Maasai. These knowledge gaps leave the region's social-ecological systems vulnerable to degradation.

In the summer of 2017, as part of the East African International Research Experience for Students (EA-IRES) fellowship, the research team travelled to Tanzania to study problematic plant species. The following questions were the basis of this research: 1) how do Maasai pastoralists define problematic species of plants using Traditional Ecological Knowledge, in comparison with Western and/or academic definitions, 2) what are specific examples of plant species that Maasai perceive to be problematic, and 3) how do problematic plants impact the environment and land-use opportunities by local Maasai communities, such as pastoralism and agriculture? The goal of this pilot study is to bring to light potential issues that problematic plant species pose on indigenous livelihoods. With this information future research projects can be developed in collaboration with local communities to aid in the identification and mitigations of plant-caused problems for Maasai.

2. Methodology

2.1. Data Collection

A rapid rural appraisal method, or rapid assessment process (RAP) was used to collect data for this study[3 13 14]. Over the course of five weeks, seven focus groups were conducted between two villages in Northern Tanzania: Sukuro and Kitiengare. Four focus groups had all female participants and three were all-male. A native translator deciphered the participants' responses from the region's indigenous language, Maa, into English for the researchers. Each focus group contained between five and 15 participants and lasted between 120 and 180 minutes. During this time, they were guided through a series of questions but given ample time to discuss and expand upon each answer. Participants were first asked a series of demographic questions that focused on their age and livelihoods.

The second part of each focus group concentrated on problematic plants. Participants were asked to freelist all the plant species they found to be problematic. Originally, these lists were separated into three functional groups of vegetation: grasses, forbs, and trees. However, it became quickly apparent that this system did not translate, and the Maasai categorization system was used: *majani* (grasses and forbs) and *miti* (woody plants). Each plant was written in the appropriate category and in either Maa or Swahili on a large sheet of paper.

Once the members of the focus groups agreed that there were no more problematic plants, participants were guided through a ranking exercise. Participatory ranking methodology (PRM) builds upon rapid appraisal in a quantitative and qualitative manner by producing numeric rankings, differing viewpoints, and open discussion[1]. This is a community-driven process that draws upon indigenous knowledge and perceptions, shedding insight on what is most relevant to locals[2]. In this instance, each participant was given two sets of three color-coded stickers labeled with their own unique identification. Red/pink corresponded with their first choice of most problematic plant, yellow with second, and blue/green with third. By placing the stickers next to the name of the plants on the vegetation list, participants identified the top three plant species they perceived to be most problematic in each category. Each ranking was assigned an inverted score and then summed; number one rankings were given a score of three, second was given two, and third was scored as one. The plants with the three highest scores were further characterized to identify problematic traits, phylogeny, and historical trends of the plants.

2.1.1. personal information

1. What is your age? (*exact)
2. What age set are you/your husband a part of?
3. Do you have livestock, a *shamba*, or both?
4. For how many years have you or your family grown crops?

2.1.2. identify problematic plant SPECIES

5. Which species of *majani* (grasses and forbs) in this area do you find to be problematic for you, your animals, your *shamba*, the environment, or anything else?
6. What problematic traits does this species exhibit?
7. What species of *miti* (woody plants) do you find to be problematic for you, your animals, your *shamba*, the environment, or anything else?
8. What problematic traits does this species exhibit?

2.1.3. ranking exercise

9. Place this sticker next to the species that is most problematic for you.
10. Place this sticker next to the species that is second most problematic for you.
11. Place this sticker next to the species that is third most problematic for you.

2.1.4. species-specific question (ONLY for top three species of each functional group)

12. What effects does this plant have on your animals?
13. What effects does this plant have on cultivation?
14. What effects does this plant have on water availability?
15. Do problems with this plant occur in the wet season, the dry season, or both?
16. How does this plant respond to flood?
17. How does this plant respond to drought?
18. You've told me this plant affects livestock __*(in this way)*____. How do your livestock affect this plant?
19. You've told me this plant affects *shambas* __*(in this way)*____. How does cultivation affect this plant?
20. Is there a place near here that you find this plant in large quantities?
21. Is it common or uncommon in highlands?
22. Is it common or uncommon in pastures?
23. Is it common or uncommon in *shambas* (cultivated fields)?
24. Is it common or uncommon in *korongos* (river channels)?
25. Is it common or uncommon in *engusero* (wetlands)?
26. Do you remember this plant from your childhood?
27. When did you first see this plant in the region?
28. Has this plant increased, decreased, or stayed the same over time? Why do you think that is?
29. What benefits does this plant provide to your or your community? Does this plant have any uses?

2.2. Data Analysis

Two indices were created to compare problematic plants: salience and severity. The salience index was used as an indicator of the prevalence of each problematic plant, whereas the severity index signified how problematic the plants were perceived to be. Both were calculated using a modified Smith's S index, which compares the mean ranking to the ranking frequency[19]. The top three most problematic scores for each group were placed next to the respective plants. All the first, second, and third place rankings were added for each plant. These ranks were then given inverted ranking scores. Total problematic scores were calculated by adding all the inverted values. This score was then normalized for each plant by dividing by the total number of ranks the plant received, producing the mean problematic score. For the salience index group reporting percentages were calculated by dividing the number of times a plant was included on the list by seven, the total number of focus groups. For the severity index ranking frequencies were calculated by dividing the number of ranks by the total number of participants, 64. The index values were the product of the mean scores and ranking frequencies.

To answer the question of how local Maasai define problematic species, researchers used batching, a qualitative data analysis method that "batches" each trait into an easily translatable code[19]. The primary open codes contained the raw data given by the participants, which express the specific problematic trait exhibited by each plant. These codes were refined into secondary selective codes, which eliminated redundant information by consolidating same/similar responses into more precise categories. Selective codes were then classified into tertiary axial codes, which promoted thematic grouping. Seven major themes emerged through this process: noxious to humans, noxious to livestock, advantageous in agricultural systems, advantageous in natural systems (pastures), nuisance, unusable, and foreign. Each is considered a unique quality of different types of invasive species[23][6], which was intentional to make the data more readily available to the scientific community. Codes were further categorized into realms of impact: human, livestock, agriculture, and environment. Each selective code was ranked by the amount of impact it created for each of the four realms: zero for no connection; one for indirect impact, two for moderately direct impact, and three for direct impact. These values were then added in each realm. It should be noted that environmental effects were not discussed by Maasai; the environmental schema was inferred based upon mentions to other similar effects such as pasture degradation and the plants' ability to colonize new areas.

3. Data

Results are based only on species within the *majani* category, which included grasses and forbs. Several groups identified *miti* species of concern, but the reports were not frequent enough to extract significant results. Therefore, researchers chose to exclude them altogether to decrease uncertainty within the results. All plant names are listed in Maa or Swahili.

3.1. Problematic Plants

Figure 1 shows the comparison of percent group reporting against the mean group problematic score. When these values are multiplied together, it produces the salience index value. Although several plants were mentioned frequently, they were not perceived to be severe enough to invoke a ranking. Many of these plants are omitted from the severity index because they procure a score of zero, which does not concern this analysis.

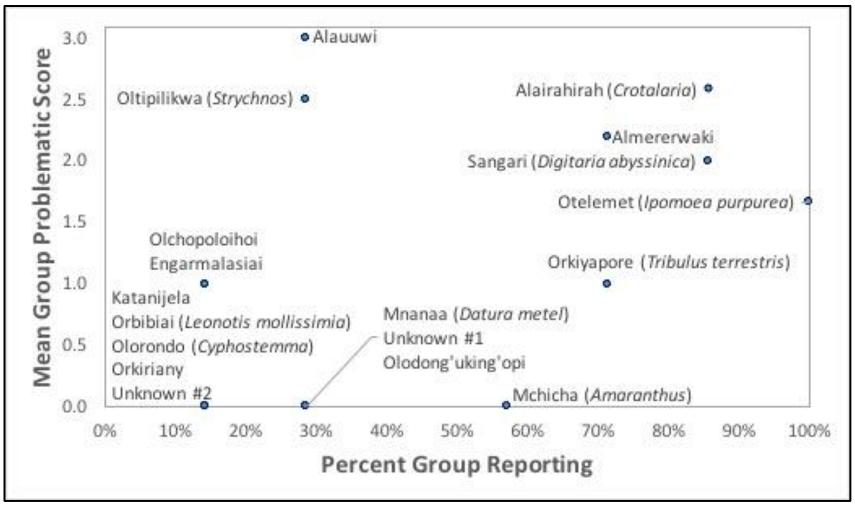

Figure 1. Comparison of mean group problematic score and percent group reporting for each problematic plant indicated by interviewees. The product of these two values is the salience index. This graphic includes scientific names for the plants that were identified[24].

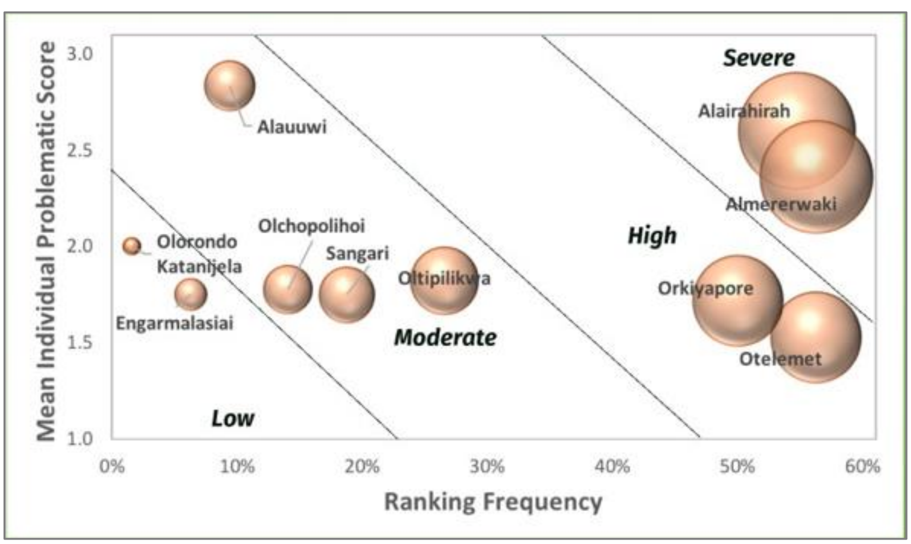

Figure 2. Severity index for the plants with salience scores greater than zero. Plants were divided into their level of severity: low, moderate, high, and severe.

The severity index value is indicated by the size of the bubble in Figure 2. Similar sized bubbles are regionally located on the graph. Based on this configuration, labels were assigned to each region: low severity, moderate severity, high severity, and severe. There are many similarities between species that were highly ranked by focus groups and individuals. However, there are a minority of plants that have disparate scores. *Sangari*, for example, was mentioned frequently, but it was not consistently ranked; however, when it was ranked it was ranked highly. This gave it a high salience score but not a high severity score. This is demonstrative of the differing information each index provides about the plants. The four species in the upper right corner of Figure 2, the high and severe categories, are of the utmost concern to Maasai. Therefore, they are used as case studies to express the variety of problems that plants can cause.

3.1.1. alairahirah – rattlepod (crotalaria)

Alairahirah is the most severely ranked plant. It is said to taste "sweet" to cows but presents in a variety of illnesses when they ingest it: nursing mothers oftentimes lose their milk, some animals develop chest colds, and others simply die from weakness. However, one of the most striking symptoms is extended hooves. This occurs when the hoof grows elongated and then wraps back on itself toward the leg. Although an accredited veterinary diagnosis was not established, it appears to be metabolic laminitis, also known as foundering. This is caused by gorging on nutrient-rich foliage, resulting in a symptom known as slipper foot[12]. Unable to walk from the pain, the cow goes lame and has to be grazed closer to the family home or slaughtered

Alairahirah is spread by animals and moving water. It is commonly found in pastures recently grazed, because livestock transport it in their manure. It has been present in Simanjiro for several Maasai generations. However, one senior interviewee remembered that it was not present during her childhood over seven decades ago, which means that *alairahirah* may be an invasive alien species to the area. Further research is necessary to investigate this discrepancy.

3.1.2. almererwaki

Almererwaki is also highly ranked by interviewees as a problematic plant. Most types of livestock can die in as little as two hours after eating the leaves and/or flowers of this plant. It is also a drainage on soil moisture, extracting groundwater from *shambas* and killing neighboring crops. The plants' seeds are encased in tough burrs with thorns, which get stuck in human and livestock feet, rendering entire pastures impassable. The burrs are susceptible to water because floods carry them away, which appears to slow regeneration. Unfortunately, the seeds are extremely drought-resistant, allowing them to lie dormant for several seasons. They are transported via animal fur, clothes, water, and vehicles, and are able to grow nearly anywhere they fall. Further research will be required to observe distribution shifts in the face of changing weather patterns.

3.1.3. orkiyapore – puncture vine (tribulus terrestris)

When cows eat the leaves of *orkiyapore*, they develop open wounds, similar to blistering burns. However, it only affects polychromatic cows (primarily black-and-white individuals), and the wounds only develop on the lighter parts of their bodies. After further investigation, it is believed that the cows are most likely experiencing primary photosensitization (D. Bunn, personal communication, October 18, 2018). Plants produce photodynamic metabolites that, when ingested, can damage cell walls. Intense ultraviolet radiation then kills the lighter epidermal cells, giving the animal a severe sunburn[15]. These wounds have been known to lead to secondary infections and occasionally death.

Orkiyapore has been witnessed by locals regionally in the area for many generations, but the first observations of its presence in Sukuro occurred in 2009. According to interviewees, it is likely the result of foreign pastoralists who migrate southward during times of extreme drought. The severe El Niño drought that occurred during the same time period that *orkiyapore* was first seen forced Kenyan pastoralists to migrate hundreds of kilometers into Tanzania in search of productive pasturelands. It is generally thought that this is how *orkiyapore* was transported to the region.

3.1.4. otelemet – morning glory (ipomoea purpurea)

Otelemet, commonly known as morning glory, was one of the few plants identified by interviewees to be non-indigenous to the region, which is why it became the most frequently ranked plant. "It comes in and takes over everything" is how one study participant defined it. The entire plant is inedible for all animals, including livestock and wildlife. Unfortunately, it is outcompeting entire pasturelands at a staggering rate, dwindling the amount of land that pastoralists can use. There are also accounts of it poisoning children who attempt to eat it. On the other hand, it was one of the few plants that was referred to positively because it provided several useful benefits. Dried branches can be used for biofuel; beekeepers in the region associate this flower with increased honey production; and the leathery leaves can be used as toilet paper.

Otelemet seeds are dispersed by water. Seeds can sprout just one week after the first rainfall following the dry season. The plant is able to develop an extensive root system and mature more rapidly than other plants. This gives the plant a competitive advantage over local grasses and crops in Simanjiro.

3.2. Problematic Traits

The degree to which each problematic trait impacts the system is shown in Figure 3. Impacts to humans and livestock are equally ranked at 47. Pastoralism is the primary livelihood of Maasai. Therefore, it is sensible that the ranking of impacts to their livestock parallels impacts to themselves. Environmental impacts received a score of 35. It should be reiterated that no environmental impacts were mentioned, other than those associated with pastures. Inferences carefully considered by the research team were made based on how the plant was discussed and how it affected similar parts of the system. Agricultural impacts received a score of 28. Crop cultivation is a dietary supplement to the Maasai food staples of milk and meat. Problems to agriculture are a secondary concern, because they do not merit the same attention that livestock and human health do.

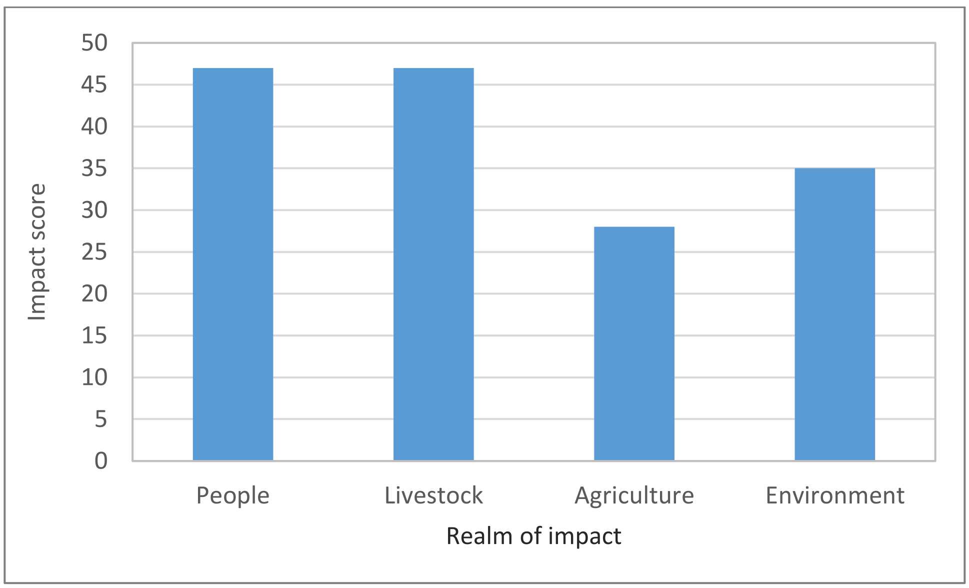

Figure 3. Quantitative effects of problematic plants on each realm of the social-ecological system.

The total number of uniquely identified problematic traits was 126. These were batched to 26 commonly identified characteristics. Some of the most common are that the plants kill crops, livestock, and children, they extract water, kill natural vegetation in pastures, and impair cultivation. Forty-two traits are considered advantageous in agricultural systems, 37 are noxious to livestock, 18 are advantageous in natural systems, 11 are noxious to humans, seven are considered a nuisance, six are simply unusable, and five are nonindigenous to the region. Figure 4 summarizes this information. A similar number of traits are found in the categories that affect livestock, pastures, and cultivation. These three areas are the primary food sources for Maasai. Additionally, the local people have developed methods to avoid problematic plants, which is why there are fewer species that are noxious to humans. However, their animals and crops may not be as well adapted to novel and invasive plants.

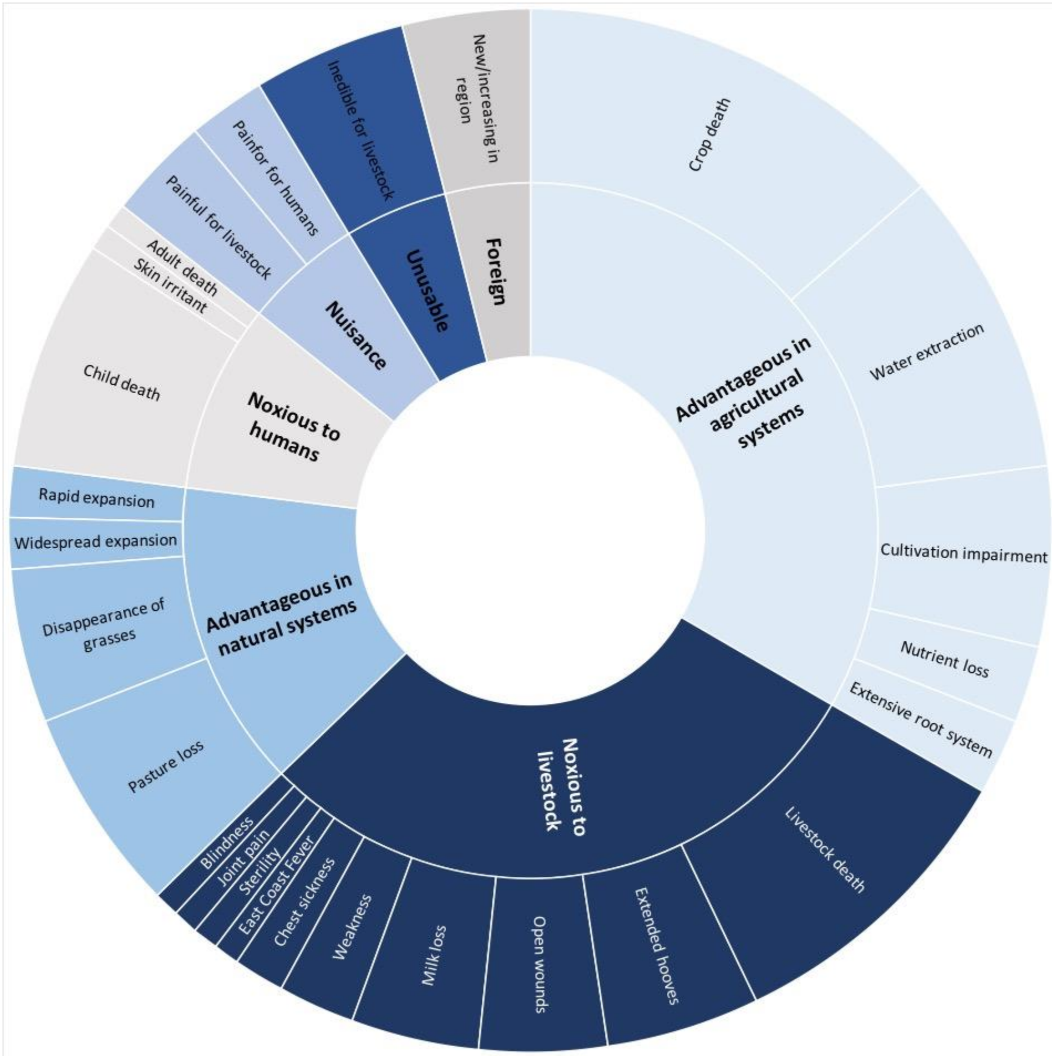

Figure 4. Coding of problematic traits. The size of each slice references how many times that code was indicated by participants as a problematic trait during focus groups.

4. Conclusion

4.1. Cultural Differences

There are several differences between Western and non-Western definitions of problematic plants. From an ecological/botanical perspective, plant species are typically perceived to be problematic to ecosystem structure and function. Contrastingly, Maasai are concerned with how the problematic plants affect their agro-pastoralist livelihoods. They did, however, talk about effects to grasses and pastures, but they do not perceive themselves to be separate from these natural systems. If the ecosystem is disrupted than so too is their life.

"Invasive" was not a characteristic that was commonly reported. If a plant appears, then it is simply there, but it does not invade. In a few select instances, plants were said to have "taken over". It was only through the coding process that the academic term "invasive" was applied to traits that were discussed.

As mentioned before, Western and Maasai communities have classification differences: "grass, shrub, and tree" are not translatable into Maa or Swahili. They categorize plants as *miti* for woody plants and *majani* for leafy plants. This played a crucial role in data collection, because the approach toward focus group questions had to be quickly changed. It also narrowed the analysis to only one category because woody species were less problematic.

Lastly, there are gender-based differences. Females tend to be more concerned with plants problematic for human health – especially that of their children. The mention of plants that children would mistake as food was exclusive to female-based focus groups. Women are the *boma* (settlement) caretakers, and are, therefore, in charge of the children. Males are focused on the wellbeing of their livestock because they tend to the animals the majority of the day. Both genders, however, discussed effects that plants have on agriculture.

4.2. Future Research

It should be mentioned again that this project was a pilot study to inquire about the plant-based problems Maasai encounter in the Simanjiro District of Tanzania. The intention is to develop future, collaborative research projects from this information. This was a rapid rural appraisal of problematic plants and their exhibited traits to guide prospective research proposals.

English is not a language that is commonly spoken in Tanzania. All the plant names that were given are in Maa or Swahili, neither of which are traditionally a written language. The next step for this project is to coordinate common and scientific names with their native names. Nine of the plants, including three of the four most severe, have been identified thus far, but the other nine are still unknown and being researched. Once the scientific names are found, literature reviews will investigate prospective solutions that may have already been discovered by other researchers. If any results do exist, the information can be disseminated to the local communities.

Unfortunately, these rural villages are considered impoverished. They do not have the financial means to complete large-scale operations for containment and eradication of the alien, invasive, or spreading species. Most of the solutions will have to be adaptive in nature. Priority must focus on treating the symptoms of the problems, rather than the root problem. For example, educational programs can be used to teach children which plants to avoid eating and veterinary practices can be taught for treating plant-borne diseases such as laminitis and bovine sunburn.

Lastly, this project focused only on perceptions of problematic plant species. Specimens were observed, and photos were taken, but the majority of the information was not verified with *in situ* measurements. Continuing this project will require a geospatial component. Field transects, satellite imagery, and seasonal comparisons will be incorporated in order to quantitatively substantiate the qualitative information provided. Additionally, future research will be able to witness how these plants change in the face of shifting weather patterns.

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