Multi-Criteria Based Evaluation of User Preferences for Drought Index

Githungo, William, Silvery Otengi, Jacob Wakhungu, Masibayi Namusasi  
*Masinde Muliro University of Science and Technology*

**Corresponding author:**  
William, Githungo  
*Masinde Muliro University of Science and Technology*  
P.O. Box 30259 00100 Nairobi, Kenya  
email: william_ndegwa@yahoo.com

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**ABSTRACT**

Drought is a natural hazard with regional characteristics and impacts the world over. Manifestation of impacts of drought in Kenya occurs in form of lost lives, livelihood disruption particularly among rural poor households, socio-economic impacts, and reduced economic growth. Decision-making based on drought early warning information aim to reduce vulnerability and improve response capacities of recipients. The provision of drought information to inform decisions presents challenges that transcend scientific advances in climate science. Availability of information on drought and its processing by target user audience is important. The overall objective of this study was to evaluate existing drought indices for their suitability for use in informing drought response actions in ASALs of Kenya. The study was done in the ASAL counties of Machakos, Makueni, and Kitui in Kenya. Using survey method user preferences for drought indices were elicited from drought researchers and professionals. Following the revised Simos procedure, the decision criteria for effective use of drought indices were evaluated. The evaluation assessed how the drought indices satisfy desirable properties of a good drought index and how they could be useful among stakeholders. Analysis indicated that respondents preferred sophistication as good property of a good drought index followed by tractability, robustness, transparency and eventually extendibility taking the lowest position.
1. Introduction
Drought early warning systems aim to reduce vulnerability and improve capacities for risk reduction. In drought management, quality of decision-making depends in part on the information available and the manner in which this information is processed by individuals, groups and systems (ICSU, 2008). Although seasonality in climate provides decision makers with indications of potential risk, the timing and form of early warning information inputs, and access to trusted guidance and capability to interpret and implement the information and projections in decision-making processes, are as important to individual users as improvements in prediction skill, Pulwarty (2007). Indicators of drought such as drought indices need be evaluated for their effectiveness in enabling action in drought management (Barua, 2010).

Desirable properties which may enable users of drought indices to measure their effective use in drought management were proposed by Redmond (1991). These properties include: (1) detailed understanding of caveats, limitations and assumptions need not be critical for proper interpretation for drought indices in wide public use, (2) indices should not be too complex; (3) indices should not be overly simplified (e.g., an index for wide expanses of land or state wide precipitation or too many variables together); (4) indices should offer improved information over raw data values; (5) for routine practical usage, historical time series of data must be readily available; recent values must be quickly computable, and both must be compatible (homogeneous record); and (6) indices should be helpful thus social and economic impacts need be proportional to the value of the index. Keyantash and Dracup (2002) revised these desirable properties into six decision criteria, namely robustness, tractability, sophistication, transparency, extendibility and dimensionality, which may be used for evaluating effective use of drought indices. Keyantash and Dracup, (2002) perceived that these criteria may give reasonable framework for evaluation of drought indices without excessive complications. Keyantash and Dracup (2002) also described some relative importance factors to account for relative importance of drought index based decision criterion. The evaluation of usefulness of drought indices therefore is necessary to assess how the drought indices satisfy desirable properties of a good drought index and how they could be useful among stakeholders.

The objective of this study was to evaluate the usefulness of drought indices in making decisions such as state declaration of drought as a disaster or decisions concerning drought response in Kenya. The study evaluated how drought indices satisfy desirable properties of a good drought index and thereby inferred usefulness for the ASAL of Kenya. The study involved eliciting preferences from users of drought indices including researchers, professionals and practitioners. Decision criteria to determine appropriate drought index was based on twelve (12) desirable properties for judging usefulness of drought indices drawn from those proposed by Redmond (1991).

2. Materials and Methodology
The evaluation of usefulness of drought indices was done in the Counties of Machakos, Makueni and Kitui. The approach involved eliciting preferences from drought researchers and professionals. The study was facilitated by means of a specifically designed survey tool to collect stakeholder preferences. Obtaining preference information on suitability of drought indices was basically informed by practice and experience of respondents. The study targeted stakeholders in drought management, who rely on drought indices for their practices and professional approaches. The population of users of drought indices in Kenya comprise of persons whose occupation is in drought hazard early warning and drought disaster response, recovery and mitigation. These include meteorological services, drought management, academic institutions and Government agriculture and environment service institutions. There are approximately, 15 groups of stakeholder institutions who are directly involved in matters of drought management in Kenya (Maina et al, 2013), which were listed in a sampling frame. Purposive sampling was used to identify respondents from the sampling frame.

The personal interview survey was conducted on eight persons representing the key stakeholder groups that use drought indices. The stakeholder groups include, Kenya Meteorological Service, National Drought Management Authority, Ministry of Agriculture Livestock and Fisheries Water and Environment and Forests and academic institutions.
These stakeholder groups were represented by professional staff in the respective organisations. Table 1 shows the distribution of respondents participating in the survey. These respondents were purposively identified due to their active usage of drought indices in their roles in drought management in the respective institutions.

Table 1: Profile of Respondents in interview on Simos-procedure

<table>
<thead>
<tr>
<th>Category of Respondent</th>
<th>Number respondents</th>
<th>Institution</th>
<th>Profession</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya Meteorological Department</td>
<td>2</td>
<td>Hydrological Division</td>
<td>Hydrologist</td>
</tr>
<tr>
<td>National Drought Management Authority</td>
<td>2</td>
<td>County Drought Office Mwingi Sub-County Drought Office Mwingi</td>
<td>Information Officer</td>
</tr>
<tr>
<td>Government Ministry of Agriculture, Livestock and water</td>
<td>2</td>
<td>Sub-County Agriculture Office Sub-County Agriculture Office</td>
<td>Agriculture Office Zombe and Mutomo Mutomo Agriculture Office</td>
</tr>
<tr>
<td>Academic Institutions</td>
<td>2</td>
<td>SEKU</td>
<td>Meteorological Department</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The details of the methodology used and the process of the analysis of preferences of characteristics of drought indices is presented in five steps as follows: computation of sample size, description of the method used to solicit preference of respondents, survey procedure, allocation of preference weights to sub-criteria and computation of preference weights.

2.1. Computation of Sample Size
The sample size $n$ was statistically determined according to Eq. (1). Since the population of study is small in size, the method proposed by the University of Pennsylvania (2015), was used as follows. The sample size necessary for estimating a population proportion $p$ of a small finite population with $(1-\alpha)$ 100% confidence and error no larger than $\varepsilon$ is:

$$n = \frac{m}{1 + \frac{m^2}{N}}$$  \hspace{1cm} (1)

$m$ is the sample size necessary for estimating the proportion $p$ for a large population. $Z_{\alpha/2}$ is the critical value from statistical tables, $P$ is the percentage of sample population to the total population, and $d$ is the accepted error percentage.

For a total population of 15 and error margin of 5%; $Z_{0.025} = 1.645$ and desired confidence level of 95%, the minimum sample size was estimated to be eight. Personal interview survey was conducted among eight persons following the a purposive sampling approach.
2.2. Soliciting User preference of Importance Factors of Drought Index

Relative importance factors of drought indices were determined based on Figueira and Roy (2002), and Kodikara et al. (2010). Five criterion of drought characteristics by Keyantash and Dracup (2002), were considered and grouped into respective sub-criteria based on Redmond (1991), so that there were two levels of sub-criteria. At the first level, the criteria denoted by $C^r$ where $r = 1, 2, 3, 4, 5$ indicated, respectively, the criteria relative to Robustness ($C^1$), sophistication ($C^2$), Transparency ($C^3$), Extendibility ($C^4$) and Tractability ($C^5$). At the second level, a set of sub-criteria indicating user relevant characteristics, relative to every group of criteria was considered and denoted $C^r(j)$ indicating any sub-criterion belonging to $C$ with $j = 1, 2, \cdots, n$.

Table 2: Hierarchical family of Preference criteria for usefulness of drought Index

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-Criteria</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robustness</td>
<td>$C^1(1)$</td>
<td>ability for a drought index to remain functioning under a large range of disturbance magnitudes (effectively perform while variables are altered)</td>
</tr>
<tr>
<td></td>
<td>$C^1(2)$</td>
<td>resistance and resilience (can operate without failure under a variety of conditions)</td>
</tr>
<tr>
<td>Sophistication</td>
<td>$C^2(1)$</td>
<td>may not be understood</td>
</tr>
<tr>
<td></td>
<td>$C^2(2)$</td>
<td>Understand the complexity of computation technique</td>
</tr>
<tr>
<td></td>
<td>$C^2(3)$</td>
<td>Understand the conceptual merits of drought characterization</td>
</tr>
<tr>
<td></td>
<td>$C^2(4)$</td>
<td>may be sophisticated but appreciable</td>
</tr>
<tr>
<td>Transparency</td>
<td>$C^3(1)$</td>
<td>available for examination and scrutiny (accessible)</td>
</tr>
<tr>
<td></td>
<td>$C^3(2)$</td>
<td>understandable by both the scientific community and the general public</td>
</tr>
<tr>
<td>Extendibility</td>
<td>$C^4(1)$</td>
<td>may be extended across time to alternate drought scenarios</td>
</tr>
<tr>
<td>Tractability</td>
<td>$C^5(1)$</td>
<td>low level of numerical computations</td>
</tr>
<tr>
<td></td>
<td>$C^5(2)$</td>
<td>less number of input variables</td>
</tr>
<tr>
<td></td>
<td>$C^5(3)$</td>
<td>less extensive database with historical data</td>
</tr>
</tbody>
</table>

i. P (Strict Preference): corresponding to a situation where there are clear and positive reasons in favor of one of two alternatives. If $a \succ b$ and not $b \succ a$ then $a \succ b$ (a is strictly preferred to b).

ii. I (Indifference): corresponding to a situation where there are clear and positive reasons that justify an equivalence between two alternatives. If $a \succeq b$ and $b \succeq a$ then $a \succeq b$ (a is indifferent to b).

iii. P− (Inverse Preference): corresponding to a situation where there are clear and positive reasons that invalidate strict preference in favor of one of the two alternatives, but they are insufficient to deduce either the strict preference in favor of the other action or indifference between both actions, thereby not allowing either of the two preceding situations to be distinguished as appropriate. If $b \succ a$ and not $a \succ b$ then $a \prec b$ (a is inversely preferred to b).

iv. R (Incomparability): corresponding to an absence of clear and positive reasons that would justify any of the three preceding relations. If not $a \succeq b$ and not $b \succeq a$ then $a \not\succeq b$ (a is incomparable to b).
2.3. Survey Procedure
The approach for the survey followed the Simos procedure (Simos 1990), and necessitated that the aim of the survey was communicated clearly to the respondents a few days in advance and questionnaires and corresponding information distributed in advance. It was also necessary to provide respondents with a good understanding of the definitions as well as the feasible ranges of the values of performance measurement. The technique used to collect information on respondents preferences followed three steps as follows:

1. The respondent was given a set of 12 cards with the name of each criterion written on each card. For the 5 criterion of evaluating drought indices (robustness, tractability, sophistication, transparency and extendibility), 12 cards, each corresponding and with a name of one of sub-criteria were given to a respondent. These cards did not exhibit any number what-so-ever in order not to induce answers. The respondent was also given a set of white cards with the same size but nothing was written on the white cards. The number of the white cards was not limited but depended on the respondents needs for the same.

2. The respondent was asked to rank the cards (with criteria written on them) from the least important to the most important based on the respondents perception of importance and informed by prior information on ways of judging usefulness of drought. The respondent ranked the cards in ascending order according to the importance he/she wishes to ascribe to the criteria. The first criterion in the ranking is the least important and the last criterion in the ranking is the most important. According to the respondents’ point of view, if some criteria have the same importance (i.e., the same weight), the respondent was asked to build the respective subset of cards holding them together with a clip or a rubber band this always being a simple matter of preference (ex aequo), of the respondent. Consequently, a complete pre-order on the whole of the 5 criteria was obtained.

3. The respondent was then asked to think about the fact that the importance of two successive criteria (or two successive subsets of ex aequo criteria) in the ranking can be more or less close. The determination of the weights took into account the smaller or bigger difference in the importance of successive criteria. So, the respondent was ask to introduce white cards between two successive cards (or subsets of ex aequo cards). The greater the difference between the mentioned weights of the criteria (or the subsets of ex aequo criteria), the greater the number of white cards. No white card means that the criteria do not have the same weight and that the difference between the weights can be chosen as the unit for measuring the intervals between weights. This unit was denoted as $u$, one white card means a difference of two times $u$, two white cards means a difference of three times $u$; and so on.

Simos (1990), proposed to process the information collected in order to attribute numerical values to the weights of criteria. Maystre et al. (1994) and Figueira and Roy (2002) introduced the revised Simos procedure which uses the data collection method described above and also overcomes the challenge of assigning numerical values (non-normalised weights), directly to each criterion. In this study, the method by Figueira and Roy (2002) was used for assigning numerical values directly to each sub-criterion.

2.4. Process of allocating Weight to Sub-Criteria
The cards method was used to obtain ordinal information on the weights of the sub-criteria. The ELECTRE-III method was used to build a ranking of different alternative user preferences on drought indices. The input data needed for the
a. A finite set of n alternatives (or actions) available to the decision maker A = {a, b, c, ...}

b. A finite set of criteria C = {C1, C2, ..., Cj, ..., Cm} with m ≥ 3. A criterion is a tool constructed for evaluating and comparing potential alternatives according to a well-defined point of view. Alternatives were evaluated according to a criterion, which results in performance levels that can be represented as an evaluation matrix for decision making analysis. For each criterion it was defined the set of all possible evaluations each criterion can lead to in order to allow the comparison of the alternatives. For this purpose, the performance of alternative ai on criterion gj, denoted as gj(ai), was evaluated. For the sake of simplicity, the maximization of gj was assumed.

c. A weight W assigned was assigned to each criterion representing its relative importance. The higher the criterion’s importance, the more weight was assigned.

d. A preference system assigned one of the three types of relations: Indifference, Preference or Incomparability.

Indifference and preference thresholds specify the discriminating power of a criterion when measuring the outranking relation between a pair of alternatives. To assess the criteria weights within a Simos’ procedure, the following variables were defined equation 3, 4 and 5:

\[ e_r = e'_{r} + 1; \]  \hspace{1cm} (3)

\[ k = \frac{z}{e}; \]  \hspace{1cm} (4)

\[ e = \sum_{r=1}^{i} e_{r}; \]  \hspace{1cm} (5)

Where:

- z is the ratio expressing how many times the last criterion is more important than the first one in the ranking;
- \( e'_{r} \) is the number of white cards between the rank r and r + 1;

The non normalized weight \( k(r) \) was computed according to equation 6.

\[ k(r) = 1 + u(e_{0} + \cdots + e_{r-1}), \]  \hspace{1cm} (6)

with \( e_{0} = 0 \).

Let \( k'_{i} = k(r) \) be the weight relative to the criterion i and let

\[ K' = \sum_{i=1}^{n} k_{i} \]  \hspace{1cm} \text{the sum of the non-normalized weights.}

The normalized weight \( K'_{i} \) is expressed using equation 7

\[ K'_{i} = \frac{100}{K} \times K_{i}; \]  \hspace{1cm} (7)

2.5. Computing Respondents Preference Weights of sub-Criteria

For each respondent the ELECTRE-III method was applied by varying the cutting level represented by a stochastic variable uniformly distributed. Then, to take into account simultaneously the sets of weights for all respondents’, the evaluation of each criterion range in an interval delimited by the maximum and the minimum weight for all respondents. The study adopted an ordinal scale on a twelve point, with increasing criteria evaluations. As such, respondents preference alternatives, were grouped on the basis of a consistent criteria (Roy, 1991), identified by a number of white cards defined as follows:

a. two alternatives with the same criteria evaluations is assigned to the same respondent’s preference class (exhaustive criteria);

b. an alternative on which a criterion value is decreased in terms of lower respondent’s preference could not be assigned to a lower class (consistent criteria);

an alternative could not be assigned to a respondent’s preference class when one criterion is dropped from the family of criteria (non-redundant criteria). For each of the sub-criteria, preference weights were computed. In this study the process of computation of preference weights was achieved using Microsoft Excel based software ‘developed in the ELECTRE type methods with a revised Simos’ procedure.

3. Results and Discussions

Results show that respondents indicated varying preferences for properties of drought indices. Similarities in preferences of drought index characteristics were also evident from among respondents of similar user groupings.
3.1. Outcome of the Survey

White cards were introduced into the respondents preferred arrangement of blank cards. The white cards were introduced to indicate respondents’ opinion on perceived difference of importance between adjacent sub-criteria. The number of white cards therefore was an indication of respondents’ opinion on perceived distance (or weighting difference), between two adjacent sub-criterion. The higher the number of white cards is an indication of the respondents’ opinion for added weighting for the adjoining criteria on the right-hand-side of the ordered arrangement of cards. The order of preference as ranked by each of eight respondents in the survey are given in table 2.

3.1.1. Representativeness of Study Population by Survey Sample

Given that the survey for user preference for drought indices interviewed eight persons on their preferences characteristics of drought index, out of a population of 15. Of the 8 respondents, each gave different opinion on their preferred characteristics of drought index. The study tested whether there is sufficient evidence to suggest that the respondents represented the true nature of the perspectives of the population at the 95% confidence level. The hypothesis proportion of the population used as the sample have the same characteristics as the population. The test hypothesis therefore was to find out if there is a significant difference between the proportion of survey sample which is used to determine preferences of use of drought indices and the population of users of drought indices who would be affected by the results of the study.

The proportion of the sample \( \hat{p} \), was mathematically computed as:

\[
\hat{p} = \frac{8}{15} = 0.53333
\]

The Hypotheses was formulated as:

\[ H_0: p = 0.5 \]
\[ H_a: p > 0.5 \]

The t score test statistic was computed as below:

\[
t = \frac{0.53333 - 0.5}{\sqrt{\frac{0.5(0.5)}{15}}} = 1.99998
\]

and the p-value \( = 2[P(t > 1.9998)] = 2(0.1038) = 0.2076 \)

Figure 1 shows the t Probability Distribution of Sample Proportion as computed

![t Probability Distribution of Sample Proportion](Source: Researcher 2015)

The study, therefore, inferred that the sample proportion presents a samples size which is well representative of the study population. The hypothesized proportion rather than the sample proportion was used in this formula because if the null hypothesis is correct, then 0.5 is the true proportion. This test is therefore not making an approximation. The rejection region of the hypothesis was computed using the t-table. Critical value of t is given as \( t_c = 1.26 \). Figure 1 shows that 1.99998 is in the rejection region. Therefore the null hypothesis \( H_0 \) is rejected. The null hypothesis was rejected at a value \( \alpha \) (significance level) greater than 20.76%. The conclusion of the test is therefore made that the sample proportion is similar to the population at p-value of 0.008.
In statistical analysis, the size of the sample need be informed primarily by the research objective, research question(s), and, subsequently, the research design (Srinivasan, 2004; Powis & Cairns, 2003). Based on research objectives, Creswell, (2002) suggested that sample size of 3-5 participants could suffice for a case study design. Given that the study of respondents preference of drought characteristics in this study was done among a specific group of respondents (users of drought indices), the study may be considered as a case. It therefore suffices to deduce that the sample size used in this study is sufficient to represent the study population.

Table 3: Ranking of Respondents Preference based on Cards

<table>
<thead>
<tr>
<th>Rank</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
</table>

From table 3, it is observed that respondents have varying preferences of drought index characteristics. Similarities are however evident from among respondents of similar user groupings (for example respondent 1 and respondent 2 (both from academic institutions), show high preference for sub-criteria C(1)1 and C(1)2. Similarly respondent 3 and respondent 4 both of which are from meteorological service indicate high preference for C(1)2 and C(5)2 respectively. Among the criterion, C1(2) was highly preferred by most (5 out of 8) of the respondents. On the other hand, all respondents indicated least preference for criteria C(1)1.

The preferences presented in table 2 were set by respondents using blank cards with only the name of respective criteria written on it. The white cards were introduced to indicate respondents’ opinion on perceived difference of importance between adjacent sub-criteria. The perceived difference of importance between adjacent criteria was represented by number of white cards. The number of white cards therefore was an indication of respondents opinion on perceived distance (or weighting difference), between two adjacent criterion. The higher the number of white cards is an indication of the respondent’s opinion for added weighting for the adjoining criteria on the right-hand-side of the ordered arrangement of cards. Figure 2 shows the distribution of white cards for each sub-criteria as placed by respondents.

The sample size of 8 respondents used in the study is sufficient for detecting user preference of drought index characteristics at the 5% level of significance. This deduction agrees with De Winter (2013), that small-sample upto N ≤ 5 can be used effectively in research. De Winter estimated the Type I error rate and statistical power of the one- and two-sample t-tests for normally distributed populations and for various distortions such as unequal sample sizes, unequal variances, the combination of unequal sample sizes and unequal variances, and a lognormal population distribution. De Winter (2013), inferred that there are no principal objections to using a t-test with sample size as small as 2.
In this arrangement, the sub-criteria C1(2), shows the greatest distance among all the criterion, which is between her adjacent neighbour C(1)1. In the respondents opinion therefore the first criteria C1(1) is perceived to be separated by greater weight distance from the second criteria C1(2). Following in this approach therefore, sub-criterion C2(3), shows the second greatest distance which is between her adjacent neighbour C(2)2.

Figure 3 shows the preference weights scored by respondents as computed using the ELECTRE III approach. It is observed from figure 2 that sub-criteria C2(3), (conceptual merits of drought characterization), scored the highest weights from the respondents; followed by C2(4), (may be sophisticated but appreciable), the lowest being C1(1) (ability for a drought index to remain functioning under a large range of disturbance magnitudes).

Table 3 shows the distribution of computed preference weights across the sub-criteria and corresponding values of standard deviation and coefficient of variation of weights ranked from highest to lowest. It is observed from figure 2 that sub-criteria C2(3), (conceptual merits of drought characterization), scored the highest weights from the respondents; followed by C2(4), (may be sophisticated but appreciable), the lowest being C1(1) (ability for a drought index to remain functioning under a large range of disturbance magnitudes. Table 4 shows some descriptive statistics of computed preference weights across the sub-criteria including values of standard deviation and coefficient of variation of weights ranked from highest to lowest. Sub-criteria C1(1), (ability of drought index to remain functioning), exhibits the lowest coefficient of variability, and lowest normalized weight and standard deviation. Thus this sub-criteria indicates a high level of convergence of respondents opinion on preference for the criteria. Sub-criteria C1(2); resistance and resilience - can operate without failure under a variety of conditions), has the highest coefficient of variability and the highest standard deviation, although its indicated normalized weight is not the highest. This situation shows differing opinion of respondents on the properties of the preferred characteristics of the sub-criteria.

Table 4: distribution of computed preference weights across the sub-criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Norm. on 1</th>
<th>s.d.</th>
<th>vc%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1(1)</td>
<td>1.316</td>
<td>0.0132</td>
<td>0.04621</td>
<td>3.51277</td>
</tr>
<tr>
<td>C1(2)</td>
<td>9.007</td>
<td>0.0901</td>
<td>5.5759</td>
<td>61.9089</td>
</tr>
<tr>
<td>C2(1)</td>
<td>9.468</td>
<td>0.0947</td>
<td>4.48207</td>
<td>47.3396</td>
</tr>
<tr>
<td>C2(2)</td>
<td>8.790</td>
<td>0.0879</td>
<td>3.2453</td>
<td>36.9184</td>
</tr>
<tr>
<td>C2(3)</td>
<td>11.362</td>
<td>0.1136</td>
<td>2.45294</td>
<td>21.5891</td>
</tr>
<tr>
<td>C2(4)</td>
<td>10.307</td>
<td>0.1031</td>
<td>1.74946</td>
<td>16.9731</td>
</tr>
<tr>
<td>C3(1)</td>
<td>7.394</td>
<td>0.0739</td>
<td>3.93155</td>
<td>53.1754</td>
</tr>
<tr>
<td>C3(2)</td>
<td>6.376</td>
<td>0.0638</td>
<td>2.97788</td>
<td>46.7067</td>
</tr>
<tr>
<td>C4(1)</td>
<td>7.392</td>
<td>0.0739</td>
<td>3.16</td>
<td>42.7507</td>
</tr>
<tr>
<td>C5(1)</td>
<td>9.362</td>
<td>0.0936</td>
<td>3.46214</td>
<td>36.9789</td>
</tr>
<tr>
<td>C5(2)</td>
<td>9.595</td>
<td>0.0960</td>
<td>3.00438</td>
<td>31.3113</td>
</tr>
<tr>
<td>C5(3)</td>
<td>9.616</td>
<td>0.0962</td>
<td>2.90827</td>
<td>30.2432</td>
</tr>
</tbody>
</table>
User preferences are best modeled as a distribution over topical-regions (called Topical-Region Preference), Hong et al., (2012). A topical-region representing an area (geographical or virtual), in which users do similar things (such as interpreting drought conditions, impacts, among others). Topical-region comprises two components: geo-location and semantics. Following with Hong et al., (2012), this study considered relative important factors of characteristics of drought indices as perceived by respondents, as a topical region and the criteria and sub-criteria as semantics which give meaning to the respective characteristics. Thus the criteria and sub-criteria were considered as research constructs whose validity are in the indicators (relative importance factors). Zhao et al., (2013), followed a combined approach to study, opinion mining and geographical modeling and concluded that Topical-Region preference do not model the user preferences on aspect level, that is, they are not able to capture directly the characteristics and features of the preference. The prior description of the criteria for use of drought index as described by Keyantash and Dracup, (2002) and subsequent sub-criteria as described by Redmond, (1991) enabled the study to capture the description of desired relevant characteristics and features of drought indices from among the respondents. Thus in this manner the study was able to overcome the challenge described by Zhao et al., (2013) and modelled the preferences with aspect represented by the sub-criteria.

The Box and Whiskers graph (figure 4) shows spread of distribution of preference weights for each criteria. The central box includes the distribution of preference weights between the 25th and the 75th percentile (that is 50% of the central distribution of preference weights). The two whiskers (plus and minus) include the whole range (min-max) of weights' distribution which in this study were used as the delimiting thresholds for computing preference weights. The lowest and highest delimiting threshold being 1.24 and 16.48 respectively.

Figure 4: Spread of Opinion on Preference Weights
These preferences represent the relative importance factors of relevant characteristics of drought indices such as basic needs, beliefs, and job context (Jones et al., 2016), of users of drought indices. From figure 3, it is deduced that the larger the box plot, it is an indicator of wide spread, of opinion among respondents for the sub-criteria. The contrast, is true that the smaller the box plot is an indicator of convergence of respondents preferences concerning the sub-criteria. The sub-criteria C1(1) shows the highest convergence of respondents opinion. This sub-criteria was also ranked and weighted the lowest indicating agreement on the low level of importance of the sub-criteria as perceived by respondents. The sub-criteria C2(2; understand the conceptual merits of drought characterization), C2(3; understand the complexity of computation technique), and C2(4; may be sophisticated but appreciable), show high convergence of preference weighting by respondents. These three sub-criteria are also some of the criteria assigned high weight by respondents. This concurrence being therefore an indication of the high level of importance that respondents attributed to the sub-criteria. This deduction is also an indication of a linear relationship between rank and weights assigned by respondents. This analysis conforms with Doyle et al., (2007), that empirical analysis of rank-weight relationship is basically linear. Bottomley and Doyle (2006) found that a maximum of 100 weight elicitation procedure, in which the most important criterion is given a weight of 100, has the highest reliability, rank-weight linearity, and subject preference.
From figure 3, the three sub-criteria C(2)1, C(2)3 and C(2)4 with high convergence of respondents opinion also belong to the main criteria of sophistication. Doyle et al., (2007), indicated the existence of a theoretical straight-line relationship between rank and average weight. The ranking of these sub-criteria with C(2)1, C(2)3 and C(2)4 showing highest convergence agrees with Doyle et al., (2007), that empirical the slope of the linear function depends on the number of criteria being ranked.

In using weighted preferences the approach follows closely with the cognitive hierarchy model of human thought and action as developed by Fulton et al., (1996). Fulton et al., (1996), developed a conceptual framework for studying human values. The framework was developed as a measurement instrument for assessing basic beliefs and value orientations concerning issues of enduring relevance to management and planning. Therefore, the user preferences indicated in this study are indications of potential characteristics of management including basic needs, beliefs and value orientations that influence the decisions of drought managers who use drought indices. Figure 5 shows cognitive hierarchy model as developed by Fulton et al., (1996).

The values indicated in figure 5 are variables matching respondents considerations on the relative importance factors of the characteristics of drought indices, made during discussions in a Simos procedure interview session. Given that these parameters were considered in the interview session of the survey, it is deduced that the interview enabled adequate solicitation of information that may be used to infer preferences of users from the weighted criteria analysis (Arlinghaus & Mehner, 2004).

Given that the survey to elicit preferences of characteristics of drought indices used an open-ended Simos approach without pre determined items, but rather seeking to capture intrinsic relative importance factors inherent in basic needs, beliefs, values, job content and informed intentions, of respondents, in their use of using drought indices, it is deduced that the survey yielded unbiased results. This deduction is in line with Arlinghaus & Mehner, (2003), that the use of open-ended questions can yield less biased results as compared to closed-ended answer formats with pre-determined items.

Figure 5: Cognitive hierarchy model of human thought and action (Source Fulton et al., 1996)
In a similar, analogue, reading from the cognitive hierarchy pyramid illustrated in figure 5, Jones et al. (2016), inferred that values such as implied in relative important factors underpin an understanding of forms of thinking and behaviour among the respective managers of environment and natural resources such as users of drought index.

Validity and Reliability of Results

Usefulness of preference ranking data was questioned by Ben-Akiva et al., (1992). Munda (2005), however, showed that Multi-criteria data analysis models such as the Simos procedure provide systematic and transparent approaches that increase objectivity and reliability of results by design. In this study, validity and reliability of results was tested by determination of relationship between preference of sub-criteria as ranked by different respondents using correlation analysis. In this method, the Spearman's correlation coefficient \( r \) (rho) was calculated using the ordinal rankings of the preference of sub-criteria derived from the survey data. In the Spearman's correlation coefficient \( r \) (rho) analysis, the ranked data was considered as ordinal data. A Spearman's correlation coefficient \( r \) (rho was calculated between the ordinal ranking of preference of sub-criteria based on total number of preference criteria and the average ranking assigned to each sub-criteria by the survey respondents. The analysis seeks to determine if a significant relationship exists between ranking on preference of sub-criteria as ranked by different respondents. The Null and Alternative Hypotheses tested were as follows:

\[
H_0: \text{There is no relationship between rankings of sub-criteria for drought indices as ranked by respondents.} \\
H_1: \text{There is a relationship between rankings of sub-criteria for drought indices as ranked by respondents} \\
\]

The difference between ranks as placed by respondents using cards was considered as the dependent and the respective rank order as the independent variable.

Both the dependent and independent variables were considered as ordinal numbers. The Spearman rank order correlation coefficient, was calculated using equation 8.

\[
r = 1 - \frac{6 \sum D^2}{N(N^2 - 1)}
\]

Table 5 shows the computed Spearman rank order correlation coefficient for preferences of sub-criteria among respondents.

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</table>

The P-value at 5% statistical significance was used to determine the statistical significance of the computed value of the Spearman correlation coefficient. The Spearman correlation analyses express the strength of linkage or concurrence between to variables in a single value between -1 and +1. A positive correlation coefficient indicates a positive relationship between the two variables while a negative correlation coefficients expresses a negative relationship. A correlation coefficient of 0 indicates that no relationship between the variables exists at all. However these correlations are limited to linear relationships between variables. Even if the correlation coefficient is zero a non-linear relationship might exist. In this analysis, correlation values above 0.75 were interpreted as very strong correlation indicating strong relationship between ranks. All the values of correlation coefficient above 0.75 were found to be statistically significant at 5% level.

The large and positive values of the Spearman's correlation coefficient indicate substantial agreement between the survey results and ranking method used.
This implies that, preferences of sub-criteria as ranked by respondents more frequently are considered important by users of drought indices in Kenya. This approach follows closely with Marichal and Roubens (2000), who determined criteria weights from partial ranking of the alternatives, individual criteria, or criteria pairs. In a similar manner it is inferred that the result support the validity of Revised Simos procedure as a tool for acquisition of respondents decisions following with Hinloopen et al., (2004), who integrated the assessment of the scores (cardinal input) and rankings (ordinal input) of the decision-makers’ preference structure. In their approach Hinloopen et al., (2004) considered that relative criteria importance is represented by a set of cardinal weights or ranks. In a similar approach Salo and Punkka (2005), described rank inclusion in Criteria Hierarchies (RICH), a multi-criteria decision making method in which ranks are given to a set of attributes, and the best alternative is chosen using certain dominance relations and decision rules. As such, it is inferred in this analysis that user preferences of criteria determined using the arrangement of cards method in a revised Simos procedure produces valid and reliable ranked preferences of sub-criteria of users of drought indices.

### 3.2. Profile of Criteria Weights

Exploiting an out-ranking relation in order to arrive at a recommendation of user preference on preferred characteristics of drought index requires application criteria techniques as implied by (Roy and Bouyssou 1996). This method was guided by application of the preference weight to the five drought criteria; robustness, sophistication, transparency, tractability, and extendibility. In determining criteria weights for individual sub-criteria as indicated by respondents, the assumption is that a universal functional relationship exists between sub-criteria ranks and average weights empirical evidence from literature (Min, 2009; Jablonský, 2009; Brans and Mareschal 2005), supports this assumption. A linear relationship between rank and weights inferred in previous section as assigned by respondents was used.

As such, the profile of weights at level 1 of criteria, (robustness, sophistication, transparency, extendibility and tractability) was determined by aggregating the respective sub-criteria (level 2) weights. The criteria weights were aggregated by arithmetic summation of all the individual sub-criteria weights supplied by individual respondents in the respective group into aggregate criteria weights. Figure 5 shows the distribution of weights for each (level 1), criteria.

![Figure 5: Distribution of Preference Weights for Criteria](image)

The approach was developed to assign weights to user preference based on relevant criteria which describe the use of the drought index. The weighting was based on ranking the sub-criterion, and subsequently to aggregate the weights into an overall group weight for each criteria. Weighting is an unavoidable step in the application of multi-criteria methods (Antunes et al., 2013) and drought related decision processes require some indication of the relative importance of the different criteria. The weighted criteria was used for assessment of preferences of user of drought indices based on the principles of selection criteria that reflect the critical elements that can be assigned a weighting follows closely with (Antunes et al., 2011; Daim et al., 2009; Tsoutsos et al., 2009). (Daim et al., 2009), agree that the approach of simply asking the participants to rank the criteria in a pair-wise comparisons is adequate for assessment of criteria weights in multi-criteria analysis processes performed in a participatory context.
In similar approaches, Tsoutsos et al., (2009) asked participants to name their priority (top) criteria only (from a seven-item-long criteria set). Antunes et al., (2011) in a problem dealing with irrigation water use applied interviews to understand the decision context in an early stage and to identified main actors in the decision problem and later performed a second round of interviews to determine criteria weights and alternative scores. Such weightings reflect the relative importance of selected criteria and scores that are based on information availed by respondents. In this study, by normalising the criteria set by cards while applying the weightings after placing the white cards allowed for the true effect and advantage of the weighting system. A similar approach was applied by Yorifuji et al., (2012), to assign weights on relation of road proximity and placenta/birth weight ratio. Given that the criteria are ranked by respondents, the assumption that this functional relationship can be used to combine the various rank inputs into a set of aggregate (group) criteria weights holds. In this respect an order of user preference for drought indices for Machakos, Makueni and Kitui region was ranked as:

1. sophistication (drought index needs be understandable including understanding the complexity of computation techniques, understanding the conceptual merits of drought characterization and needs also be appreciated by users);
2. tractability (drought index needs to have low level of numerical computations, less number of input variables and less extensive database with historical data);
3. robustness (drought index needs to have ability for to remain functioning under a large range of disturbance magnitudes (i.e. effectively perform while variables are altered);
4. transparency (available for examination and scrutiny; understandable by both the scientific community and the general public) and
5. extendibility (drought index may be extended across time to alternate drought scenarios).

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5. extendibility (drought index may be extended across time to alternate drought scenarios).

Statistical analysis of consumer preference often utilizes trained consumer panel to show significant results (Robbins, 2003). The use of techniques such as the Simo’s procedure, with guiding criteria used in ranking the preference as applied in this study enables the analysis to achieve precision (Smith et al., 2003), by factoring out much of the individual panelist personalised variation. Jones et al., (2016), described values as understood in the fields of environmental and natural resource management. According to Jones et al., (2016), values represent deeply held, emotional aspects of people’s cognition and can complement the use of other cognitive constructs, such as knowledge and mental models. In ranking the cards based on sub-criteria, the respondents expressed preferred values for drought indices, which in this manner is considered a research construct representing the respondents knowledge and mental model of a drought index.
Following with Dorner (1996); Stanovich (1999), the ranking of respondents preferences therefore not only considered the cognitive skills, but also cognitive attitudes which are crucial for effective decision making in complex drought management problems which make use of drought indices. The choice of sophistication as much preferred characteristic by respondents is an indication of behavioural attributes and habits among the users of drought indices. In agreement with Dorner (1996), these behavioral attributes and habits concern the challenges in the way users of drought indices formulate goals, and interpret outcomes against expectations, balanced upon emotional responses like humility, curiosity, frustration and blame-shifting, which also have a significant influence on how effectively job content is achieved within complex situations drought early warning and monitoring information.

The high preference of a characteristic such as sophistication and tractability as in this study, may also be seen as an indication of respondents perception of tangible, constructive means to improve problem-solving in complex settings as is inherent in drought index models (Hardy et al. 2010). According to Hardy et al (2010), these issues are intrinsic of preferred characteristic as research constructs and are interestingly, effective cognitive issues which enable tolerance of high level of uncertainty, such as is inherent in information and thereby in this case enable the users of drought indices to acknowledge mistakes, compelled to search for counter evidence and self-reflection in the operational use of drought indices. Thus the preference of sophistication followed by tractability characteristic criteria in drought index brings out a more widespread awareness of necessity of effective decision making for users of drought indices, possibly leading to improvements in drought management which support rural livelihoods activities.

4. Summary and Conclusion

In this study, an empirical methodology was used to evaluate usefulness of drought indices. The approach was developed to assign weights to user preference based on relevant criteria which describe the use of the drought index. The weighting was based on ranking the sub-criterion, and subsequently aggregating the weights into an overall group weight for each criteria. In determining criteria weights for individual sub-criteria as indicated by respondents, the assumption is that a universal functional relationship exists between sub-criteria ranks and average weights. Given that the criteria are ranked by respondents, consideration was made that the assumption that this functional relationship can be used to combine the various rank inputs into a set of aggregate (group) criteria weights holds. Analysis indicated that users prefer drought indices which would enable reasonable understanding of the conceptual merits of drought characterization, understand the complexity of the computation techniques of the DI, and the drought index needs be appreciated. Users of DI preferred characteristics of drought index particularly belonging to the sophistication criteria.

From the results and discussion it is inferred that users of drought indices perceive that knowledge of sophistication and tractability as characteristic of drought indices give useful learning, attitudes that foster overall enablement of users of drought indices to understand the functioning, causal relations, system behaviour, specific skills related to their job content in drought management.

This study therefore concludes that indications of drought index characteristics (robustness, tractability, sophistication, transparency, extendibility and dimensionality) are necessary knowledge for users of the index to enable effective drought early warning information. More so the indications of the sophistication and tractability enable effectiveness and enhance capability of users of drought indices in their job content of drought management.
Recommendation
Most research in drought management have concentrated on development of drought indices with little or no attention to generation of useful information which would enable development of drought early warning information. More research therefore is necessary to understand the complex situation of interpreting a drought index (a figure) into drought early warning information, and the relevant application among users.

References


Barua S., (2010), Drought Assessment and Forecasting Using a Nonlinear Aggregated Drought Index, PhD Thesis, School of Engineering and Science Faculty of Health, Engineering and Science Victoria University, Australia


Min, W. 2009. Decision on priority of controlling non-point source pollution in upper stream of Soyang lake by using multicriteria decision making techniques. MS Theses, Seoul National University.


