ORIGINAL ARTICLE

Farmers' participatory forage cowpea (*Vigna unguiculata*) variety selection in the mid Rift Valley areas of Ethiopia: application of hierarchical decision making model

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ABSTRACT

Cowpea is one of the most important crops of dryland farmers with wide genetic diversity for growth habit; biomass and bean seed yield, resistance/ tolerance to biotic and abiotic stresses, and responsiveness to inputs. In the present study, farmers' participatory forage cowpea variety evaluation and selection was carried out (using a hierarchical decision making Multi Criteria Analysis model) at three districts (Adama, Boset and Mieso) in the mid Rift Valley areas of Ethiopia. Farmers compared and rated six selection criteria and four candidate forage type cowpea varieties pairwise. The results showed that, on average, farmers rated resistance / tolerance to drought as most important selection criterion followed by higher bean seed and biomass yields. Among the candidate varieties, farmers rated variety ILRI-9334 as better in terms of resistance/ tolerance to diseases, insects and droughts. On the other hand, variety ILRI-11110 was rated as early maturing, whereas variety ILRI-9352 was described as high bean seed and biomass yielder. However, based on the aggregated final weights, among others, the cowpea candidate variety ILRI-9352 was rated as the best genotype. Based on this it can be concluded that, though local level differences might justify needs for specialized variety, future research on cowpea by and large, need to prioritize dual purpose varieties that combine drought resistance and high seed cum forage biomass yield.

Key words: farmers' selection, forage cowpea variety, multicriteria analysis,

INTRODUCTION

The Mid Rift Valley part of the Ethiopian Rift Valley system is a semi-arid area characterized by inherently low and erratic rainfall-inadequate to support crop production (Biazin and Sterk, 2013). Crop yield reduction and frequent grain harvest failures are common characteristics (Biazin and Sterk, 2013) that explicated agro-pastoral system to prevail. Over the years, however, in many parts, crop production has gained importance as a dominant occupation primarily owing to the increase in human population, development of early maturing and drought tolerant crop varieties (Garedew et al., 2009). As a result, substantial quantity of grazing lands - once used to sustain herds- have gone to food crops production– leading to decline in availability of grazing lands, shortage of feed both in quality and quantity, and environmental degradation (Tessema et al., 2011).

As way forward, farmers in the area have recently embarked on alternative means of sourcing feeds. One such example includes the use of grain crops' thinnings, leaf stripings, weeds (Mekasha et al., 2014), and in some cases allocation of plots of land for cultivation of grain crops at high population density to serve as feed crop (Mekasha, personal observation).

Such farmers' initiatives, however, lacked crop varieties of ideal type that maximizes benefit as forage crop. On the other hand, researchers in the field are making effort at best to identify forage type materials adapting to the local condition. As a result, over the past decades alone, a number of forage grass and legume species have been recommended (Assefa, 2012), but farmers adoption of these materials have been very low (Tefera et al., 2010) and remained unchanged over the last three to four decades (Mekasha et al., 2014).

There could be many underlying factors, but the most important ones could be shortage of land and mismatch between farmers' and researchers' crop selection criteria. Farmers are land constrained and often value a crop on multiple criteria such as higher grain yield and simultaneously higher crop residue/ stover yield, while researchers select a crop variety to meet specific criteria- either higher grain or higher biomass yield.

Faced with such multiple problems, farmers are often reluctant to adopt specialized higher grain or fodder yielding crops. They are adherent to the low yielding, but multipurpose traditional crop varieties, and prefer versatile alternatives that outshine all others in every criteria. On the other hand, selection or development of such type crop variety is most challenging for researchers. This could partly be because of the inherent tradeoffs among important traits, and also lack of multi criteria weighing tools and techniques in the conventional selection approaches that target specific purpose.

On the other hand, recent studies have demonstrated that hierarchical decision making models such as the Multi Criteria Analysis are widely in use for handling multiple selection criteria and alternatives in fields of agriculture (Hartwich and Janssen, 2000; Adimassu et al., 2010), transport (Rousis et al., 2008), waste management (Tzeng et al., 2005), natural resource management (Mendoza, 1999; Mendoza and Martin, 2008); Hajkowicz,. 2008; Marcikić and Radovanov, 2011; Garmendia and Gamboa, 2012; Siddayao et al., 2014). This study was, therefore, conducted with aim of identifying farmers' most preferred cowpea (*Vigna unguiculata*) genotypes and selection criteria using Multi Criteria Analyzing Hierarchical Decision Making Model in the mid Rift Valley areas of Ethiopia.

MATERIALS AND METHODS

Analytical Hierarchy Process (AHP)

AHP is a multi-criteria decision-making system developed in 1980s (Saaty, 1980) to solve complex decision-making problems which involve many stakeholders, several alternative possible outcomes and many criteria by which to assess the alternative outcomes (Saaty, 2008; Adimassu et al., 2010; Garmendia and Gamboa, 2012). AHP is built- in such a way that every decision making subjects are explained within a hierarchical structure known as decision hierarchy tree, in which the objective is sated at the first level, rival alternative outcomes at the last level, and the decision criteria at the mid-level (Saaty, 2008; Mortazavi et al., 2009; Lepetu, 2012).Once the hierarchy is built, the decision makers can systematically evaluate the various alternative outcomes and criteria, comparing them to one another in pairs(Saaty, 2008; Garmendia and Gamboa, 2012). In making the comparisons, the decision makers can use concrete data about the alternative outcomes and criteria, or they can use their judgments about the alternative outcomes and criteria's relative meaning and importance (Saaty, 2008).The general analytical steps are described here under.

Creating the decision milieu/ determination of objectives

The first step in AHP involves setting decision objectives that can be shared by all stakeholders in the AHP. The objectives indicate the direction of state of change of a system desired by the decision makers. The objective should be clear, specific, measurable, agreed and realistic (Lepetu, 2012). For this particular study, the decision objective was set by experts to screen forage cowpea variety that contributes to the farmers' efforts of alleviating scarcity of feed.

Identification of decision alternatives / options

Once the objectives are identified and defined, the second step in AHP is to identify alternatives/options that are to be compared for their contribution in achieving the objectives. The alternatives/options should be independent and should compete more or less for the same resources. In this study, four alternative candidate forage cowpea varieties namely ILRI-9334, ILRI-9352, ILRI-11110 and ILRI-9626, prescreened for National Variety Verification Trial were used. The candidate varieties were evaluated for two years across different environments, and were found stable in yield and tolerance to biotic and abiotic stresses. Each variety was sown on a net plot area of 10x10 m each on model/ role farmers' field at Adama, Boset and Mieso districts. Under each model/ role farmer, a group of 20 farmers (at each district) were organized to follow him/her throughout the experimental period. Farmers provided free labor for the various activities of the experiment including land, tillage, sowing, weeding, cultivation, guarding and harvesting, whereas researchers did provision of seed, fertilizer and technical knowledge. At each district, the climate (rainfall and temperature) patterns, disease and pest incidences were the same as the long term average for the study area.

Identification of decision criteria

Following the settings of the decision objective and the alternatives, the third step in AHP is to decide on how to compare/ judge the contributions of the different alternatives/ options towards achieving the objective (Prabhu, et al., 1999; Hartwich and Janssen, 2000). This requires selection of criteria to reflect performance in meeting the objectives. Each criterion must be able to assess how well a particular alternative/ option is expected to perform in relation to the criterion. In this study six criteria (resistance to disease. resistance to insect, tolerance to drought, earliness, biomass yield and bean seed yield were identified by researchers in discussion with the model farmers and agreed up on by other participating farmers to adequately judge the relative importance of each candidate forage cowpea varieties

Performance evaluation/ Determination of the effects

In AHP, the performance of the alternatives/ options are assessed according to the measurable criteria identified (Prabhu, e al., 1999; Hartwich and Janssen, 2000). In this experiment, farmers were asked to rate the candidate forage cowpea varieties by assigning score of 1 to 9 scales meant to designate a verbal judgment score of equally important (1), moderately more important (3), strongly more important (5), very strongly more important (7) and, extremely more important (9) with 2, 4, 6 and 8 scores as intermediate values on each criterion.

Formulating relative weights/ local priorities / pairwise comparison matrix

Different criteria might have different levels of importance to each farmer/ group of farmers in the different districts, and this difference has to be reflected in the comparative judgment that farmers do assign to each criteria. To do this, all criteria were listed as column and row headings of the matrix. Group of farmers at each district were asked to compare and judge. Comparisons were made pairwise between each criterion. Farmers' consensus judgment scores were written at the intersections as interval scales to denote relative strength of the criteria in the row over the column, and reciprocal in case the criteria in the column heading was given strength over the one in row. These judgments were used to compute relative weights to each criterion first by calculating sum of each column and then normalizing values in each column by dividing each by the calculated column sum. The normalized values were then summed up row wise and each divided by the number of criteria to get relative weights of each criterion as indicated in Hartwich and Janssen (2000), Saaty (2008) and Kousalya et al. (2012). The same procedure was followed to establish local priorities for the alternatives with respect to each criterion as indicated in Hartwich and Janssen (2000), Saaty (2008) and Kousalya et al. (2012).

Consistency of the subjective rating

Prior to aggregating final weights, measuring the consistency of the subjective rating for each pairwise comparison matrix is required (Saaty, 2008; Mendoza et al., 1999; Hartwich and Janssen, 2000; Marcikić and Radovanov, 2011). Accordingly, to determine consistency of the subjective rating, consistency ratio was computed first by multiplying the column totals for each criterion (scores assigned by farmers) by the calculated relative weights for each criterion and adding the results and then subtracting the number of criterion from the added results. Then after, dividing the results by the number of criterion less one gave consistency ratio as indicated below.

$$CR = ((\sum CT.\ RW) - n) / (n-1)$$

Where,

CR= consistency ratio.

CT= column totals for each criterion.

RW= relative weights for each criterion.

n = number of criterion.

In literatures a tolerance consistency ratio of 10% was set for comparisons involving no more than 9 elements (Mendoza et al., 1999; Hartwich and Janssen, 2000; Marcikić and Radovanov, 2011). Then after, decisions that contributed to inconsistency in the judgment were pinpointed to improve consistency. This was done by analyzing consistency of each comparison in the matrix. First each values assigned by the farmers were multiplied by the ratio of relative weight of the two criteria being compared, and that calculated value with the lowest outcome (from all entries) was considered as most inconsistent

(Mendoza et al., 1999; Hartwich and Janssen, 2000). Hence to improve inconsistency of this most inconsistent judgment, the assigned pairwise comparison value of the two criteria compared was changed in the direction of the ratio of relative weight of the two criteria compared as recommended by Mendoza et al. (1999), Marcikić and Radovanov (2011) and Kousalya et al.(2012).

Aggregating/ calculating final weights with respect to objective

Once the desired consistency level was attained, the final weight for each criterion was determined by combining the weighted scores. There are different MCA methods used in literatures to combine weight, each with their own way of aggregation, but the most commonly used method- linear additive model (Mendoza et al. 1999; Hartwich and Janssen, 2000; Hajkowicz, 2008)- was used to aggregate final results of the present study. Accordingly, the values source assigned to the consequences of an alternative/ option on all the criteria are multiplied by the respective weights assigned to the criterion and then products were summed across all the criteria as given below.

$$Yi = w1si1 + w2si2 + \cdots + wnsin = \sum_{j=1}^{n} wjsiji$$

Where,
Yi= overall weight of alternative i
wj= local priorities of the pairwise comparisons of selection criteria j
sij= local priorities of the pairwise comparisons of alternative i on criteria j

RESULTS AND DISCUSSION

Decision criteria

The computed local priorities, from the pairwise comparison matrix, given in Table 1 revealed that as a selection criterion, farmers gave the highest priority for tolerance to drought (28%) followed by higher seed yield (22%) and biomass yield (20%). On the other hand, lowest priority value was given for resistance to insects (8%). The priorities attached to the criteria, however varied with location (district). As is evident from the table at Adama the highest priorities were given to resistance to drought (29%) and the lowest to resistance to insects (8%), whereas, at Boset the highest priority was given to resistance to drought (30%) and the lowest to disease resistance (5%). Likewise, at Mieso, the highest priority was given to bean seed yield (27%) and the lowest for resistance to insects (6%). The highest priority given by farmers for resistance to droughts, as a selection criterion, could be justified by the general fact that the area is moisture stressed where drought and crop failures are common phenomenon (Biazin and Sterk, 2013), and the variability observed in the ratings of the selection criteria could be because of local level differences in need (purpose) of the crop. The highest priorities attached to the bean seed yield at Mieso could thus be because of relatively more frequent crop failures (Admasu et al., 2011) that explained shortage of food and hence demand for seed.

Table 1. Local priorities of the pairwise comparisons of selection criteria

Selection criteria	Local priority			
	Adama	Boset	Mieso	Overall
Resistance to diseases	0.16	0.05	0.10	0.10
Resistance to insects	0.08	0.10	0.06	0.08
Earliness	0.11	0.13	0.14	0.13
Biomass yield	0.22	0.18	0.19	0.20
Resistance to droughts	0.29	0.30	0.24	0.28
Higher bean seed yield	0.14	0.24	0.27	0.22
Consistency	0.10	0.10	0.09	

Farmer's judgment of alternatives based on each criterion

With respect to resistance to diseases, the computed local priorities (Table 2) showed that famers prioritized the candidate variety 9334 as better resistant to diseases (37%), whereas the candidate varieties 9352, 11110 and 9626 were given the same low priority values (22%) being described as less resistant to diseases. However, the priorities attached to the candidate varieties, varied across locations (districts). At Adama and Boset farmers prioritized the candidate variety 9334 (≥45%) as better resistant, and conversely the candidate varieties 9626 and 9352 as least resistant, respectively. At Mieso however, the highest priority was given to 9352 (34%) and the lowest to 11110 (13%). The discrepancies could be attributable to local level differences in disease causing, and disease predisposing factors as well as variations in susceptibility of the candidate varieties as observed by Singh and Allen (2016) in a similar studies.

Table 2. Local priorities of the pairwise comparisons of alternatives with respect to resistance to disease.

Alternative Variety	Local priority			
	Adama	Boset	Mieso	Overall
ILRI- 9334	0.45	0.49	0.18	0.37
ILRI- 9352	0.19	0.12	0.34	0.22
ILRI- 11110	0.33	0.20	0.13	0.22
ILRI- 9626	0.05	0.24	0.37	0.22
Consistency	0.07	0.09	0.06	

With regard to resistance to insects (Table 3), farmers weighted the highest resistance priority value to the candidate variety 9334 (36%), and conversely the lowest to 9352 (19%). Location wise, however, the priorities given to the candidate varieties varied. At Adama, the highest priority value was given to 9334 (41%) and the lowest to 9626 (05%). Similarly at Boset, the highest priority value was attached to 9334 (43%), and the lowest to 9352 (13%). At Mieso, top priority value was given for 9626 (32%) and conversely the lowest for 9352 (21%). As in the case of resistance to disease, the differences in susceptibility of the candidate varieties could thus be attributable to local level differences in prevalence of insect pests and the inherent variability among the candidate varieties as reported by Singh and Allen (2016) in a similar studies.

Table 3. Local priorities of the pairwise comparisons of alternatives with respect to resistance to insect.

Alternative Variety	Local priority Adama	Boset	Mieso	Overall
ILRI- 9334	0.41	0.43	0.24	0.36
ILRI- 9352	0.23	0.13	0.21	0.19
ILRI- 11110	0.30	0.18	0.23	0.24
ILRI- 9626	0.05	0.30	0.32	0.22
Consistency	0.08	0.07	0.08	

As to the earliness (Table 4), farmers assigned the highest priority value to the candidate variety 9334 (45%) and conversely the lowest to 11110 (04%), indicating that compared to the other, candidate varieties 9334 is late maturing while candidate variety 11110 is early maturing. However, the priorities assigned to the candidate varieties varied among locations. Among others, at Adama, the candidate variety 11110 (45%) was prioritized as early maturing, whereas the candidate variety 9334 (0.4%) was prioritized as late maturing. At Boset, the candidate variety 9334(05%) was prioritized as late maturing, and conversely 11110 (46%) as early maturing. At Mieso however, the candidate variety 9352 (18%) was prioritized as late maturing and conversely 11110 (44%) as early maturing.

Table 4. Local priorities of the pairwise comparisons of alternatives with respect to earliness.

Alternative Variety	Local priority Adama	Boset	Mieso	Oerall
ILRI- 9334	0.04	0.05	0.19	0.09
ILRI- 9352	0.23	0.26	0.18	0.22
ILRI- 11110	0.45	0.46	0.44	0.45
ILRI- 9626	0.30	0.25	0.20	0.25
Consistency	0.06	0.08	0.05	

In terms of biomass production (Table 5), farmers prioritized the candidate variety 9352 (46%) as the highest yielder and conversely 11110 (12%) as least yielder. The high biomass yielding priority values assigned to 9352 was consistent across environment. However, the varieties rated as least yielder varied across locations. At Adama, the candidate variety 9626 (12%) was prioritized as least biomass yielder, but at Boset and Mieso it was the candidate variety11110 which was prioritized, as least yielding. The low biomass yield of 11110 could be attributable to low dry matter accumulation due to its earliness. Likewise, the late maturing candidate variety 93344 was prioritized as high biomass yielder, and that might be related to the prevalence of drought and the low moisture availability that might have restricted high biomass accumulation of the candidate variety (da Silveira et al. 2001; Ahmed and Suliman, 2010).

Table 5. Local priorities of the pairwise comparisons of alternatives with respect to biomass yield.

Alternative	Local priority			
Variety	Adama	Boset	Mieso	Overall
ILRI- 9334	0.14	0.34	0.22	0.23
ILRI- 9352	0.50	0.38	0.49	0.46
ILRI- 11110	0.26	0.06	0.05	0.12
ILRI- 9626	0.12	0.24	0.25	0.20
Consistency	0.08	0.09	0.07	

The computed local priorities for drought tolerance (Table 6) showed that farmers across all locations (districts) prioritized the candidate variety 9334 (40%) as most tolerant to drought, and conversely the early maturing candidate variety 11110 as the least tolerant. However, the priority values attached to the candidate varieties varied across locations. Lowest priority value was given to the candidate variety 9626 at Adama (05%), to 9352 at Boset (05%) and to 11110 at Mieso (04%). The consistently high priority value attached to the candidate variety 9334 could be an indication of genetic stability for wider environment in moisture stressed areas, and this might be because of the stay green character associated with late maturity (Hayatu and Mukhtar, 2010).

Table 6. Local priorities of the pairwise comparisons of alternatives with respect to tolerance to drought.

Alternative Variety	Local priority			
	Adama	Boset	Mieso	Overall
ILRI- 9334	0.45	0.45	0.30	0.40
ILRI- 9352	0.25	0.05	0.26	0.19
ILRI- 11110	0.26	0.23	0.04	0.18
ILRI- 9626	0.05	0.27	0.41	0.24
Consistency	0.05	0.04	0.06	

Based on bean seed yield potential of the candidate varieties (Table 7), farmers across the three locations consistently prioritized candidate variety 9352 as high yielding, and conversely the late maturing candidate variety 9334 was prioritized as least yielder. At Boset however, candidate variety 9626 was prioritized as high yielder on par with 9352. Compared to the other candidate varieties, the low bean yield of 9334 might be related to occurrence of terminal moisture stress that often coincide with periods of flowering and pod filling, and inhibits translocation of assimilates from vegetative source to the sink maturity (Ahmed and Suliman, 2010; Hayatu and Mukhtar, 2010).

Table 7. Local priorities of the pairwise comparisons of alternatives with respect to seed yield.

Alternative	Local priority			
Variety	Adama	Boset	Mieso	Overall
ILRI- 9334	0.05	0.07	0.07	0.06
ILRI- 9352	0.43	0.38	0.48	0.43
ILRI- 11110	0.32	0.22	0.25	0.26
ILRI- 9626	0.19	0.38	0.22	0.26
Consistency	0.10	0.09	0.05	

The final weight with respect to objectives

The final preference weights with respect to objectives, (Table 8), showed that over all, farmers prioritized the candidate variety 9353 as a variety of first preference followed by 9334, 9626 and 11110 in a decreasing order of importance. At a local level; however, the weighted preference priories given to the candidate varieties varied. At Adama and Bost, more preference was given to the late maturing candidate variety 9334; whereas at Mieso, candidate variety 9352 was prioritized as the first variety of choice. The highest priority given to the candidate variety 9352 might be related to the perceived better biomass and bean seed yield potential of the variety, and conversely the more local level preference seen at Mieso for the candidate variety 9334 might be related to its preference for better disease, insect and drought resistance/ tolerance. This indicates that farmers' preference for a variety depends on perceived local level constraint of production.

Table 8. Final priorities with respect to the objective

Alternative	Global priority			
Variety	Adama	Boset	Mieso	Overall
ILRI- 9334	0.35	0.33	0.19	0.25
ILRI- 9352	0.32	0.21	0.36	0.31
ILRI- 11110	0.30	0.21	0.18	0.23
ILRI- 9626	0.11	0.27	0.29	0.24

CONCLUSION AND RECOMMENDATION

Dual or muli-purpose crop varieties which are resistant/ tolerant to wide spectrum of biotic and abiotic stresses are important particularly for resource poor farmers who cannot afford to use specialized high input and management requiring crops and crop varieties. Cowpea is one of such important crops with wider genetic diversity for growth habit; biomass and bean seed yield, resistance/ tolerance to biotic and abiotic stresses, and responsiveness to inputs. In the present study farmers' participatory muli-criteria forage cowpea variety evaluation and selection using a hierarchical decision making models revealed that among others, farmers in the mid Rift Valley areas of Ethiopia, on average, valued resistance/ tolerance to drought as important selection criterion followed by higher seed and biomass yields. Among the candidate varieties, farmers valued varietyILRI-9334, as better in terms of, resistance/ tolerance to diseases, insects and droughts. On the other hand, variety ILRI-11110 was rated as early maturing, whereas variety ILRI-9352 was described as high seed and biomass yielder. However, based on the aggregated final weights, among others, the cowpea candidate variety ILRI-9352 was rated as the best genotype. In a nutshell, it can be concluded that though local level differences might justify needs for specialized variety of specific characteristics such as seed or forage biomass, future research on cowpea by and large should prioritize development of drought resistant/tolerant dual purpose (seed cum biomass/ food cum feed) varieties for the mid Rift Valley and similar areas of the country.

REFERENCES

Adimassu, A, Kessler, A, Yirga, C. and Stroosnijder, L. 2010. Mismatches between farmers and experts on Eucalyptus in Meskan Woreda, Ethiopia. In Gil L, Tadesse W, Tolosana E &López R, (Eds). Eucalyptus species management, history, status and trends in Ethiopia. Proceedings from the congress held in September 15th-17th, 2010, Addis Ababa, Ethiopia.

Admasu, H, Bekele, D and Tegegn, A. 2011. Participatory action research for climate change adaption in Mieso area. Research report No. 89. Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.

Ahmed, FE and Suliman, AS. H. 2010. Effect of water stress applied at different stages of growth on seed yield and water-use efficiency of Cowpea. Agriculture and Biology Journal of North America 2151-7525.

Assefa, G. 2012. Retrospect and prospects of forage and pasture crops research in Ethiopia. In: Assefa G, Degene M, Hanson J, Anemut G, MengistuS, Mengistu A. (Eds.), Forage seed research and development in Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia, pp. 7–14.

Biazin, B, Sterk, G. 2013. Drought vulnerability drives, land-use and land cover changes in the Rift Valley dry lands of Ethiopia. Agriculture, Ecosystems and Environment 164,100–113.

da Silveira, JAG, da Costa, RC and Oliveira, JTA. 2001. Drought-induced effects and recovery of nitrate assimilation and nodule activity in cowpea plants inoculated with Bradyrhizobium spp. under moderate nitrate level Brazilian Journal of Microbiology 32:187-194.

Garedew, E, Sandewall, M, S¨oderberg, U, Campbell, BM. 2009. Land-use and land-cover dynamics in the central Rift Valley of Ethiopia. Environmental Management. 44: 683–694.

Hajkowicz, S. 2008. Rethinking the economist's evaluation tool kit inline of sustainability policy. Sustainability: Science, Practice and policyhttp://ejournal.nbii.org 17-24.

Hartwich, F and Janssen, W. 2000.Setting research priorities: an example from agriculture using the Analytic Hierarchy Process. Research Evaluation 9 (3): 201–210.

Hayatu, M and Mukhtar, FB. 2010. Physiological responses of some drought resistant cowpea genotypes (Vigna unguiculata (l.)Walp) to water stress. Bayero Journal of Pure and Applied Sciences, 3(2): 69 – 75.

Kousalya, P, Reddy, GM Supraja, S and Prasad, VS. 2012.Analytical Hierarchy Process approach – An application of engineering education. Mathematica Aeterna 2(10):861-878.

Lepetu, JP. 21012. The use of analytic hierarchy process (AHP) for stakeholder preference analysis: A case study from Kasane Forest Reserve, Botswana. Journal of Soil Science and Environmental Management. 3(10): 237-251.

Marcikić, A and Radovanov, B. 2011. A decision model for outsourcing business activities based on the analytic hierarchy process. International Symposium Engineering Management and Competitiveness 2011 (EMC2011) June 24-25, 2011, Zrenjanin.

Mekasha, A, Gerard, B, Tesfaye, K, Nigatu, N, Duncan, AJ. 2014. Inter-connection between land use/land cover change and herders'/farmers' livestock feed resource management strategies: a case study from three Ethiopian eco-environments. Agriculture, Ecosystems and Environment 188:150–162.

Mendoza, GA and Macoun, P, Prabhu, R, Sukadri, D, Purnomo, H and Hartanto, H. 1999. Guidelines for applying multi-criteria analysis to the assessment of criteria and indicators. In: the criteria & indicators toolbox series. Center for International Forestry Research (CIFOR), Jakarta, Indonesia.

Mendoza, G.A., Martins, H. 2006. Multi-criteria decision analysis in natural resource management: A critical review of methods and new modeling paradigms. Forest Ecology and Management 230: 1–22.

Mortazavi M, Ghanbari L, Rajabbeigi M and Mokhtari H. 2009. Prioritizing agricultural research projects with emphasis on analytic hierarchy process (AHP). EFITA conference '09, Tehran, Iran.

Prabhu, R., Colfer, CJP and Dudley, RG.1999. Guidelines for developing, testing and selecting criteria and indicators for sustainable forest management. In: Guidelines for applying multi-criteria analysis to the assessment of criteria and indicators, Center for International Forestry Research (CIFOR), Jakarta, Indonesia.

Rousis, K, Moustakas, K, Malamis, S, Papadopoulos, A, Loizidou, M. 2008. Multi-criteria analysis for the determination of the best WEEE management scenario in Cyprus. Waste Management 28: 1941–1954.

Saaty, TL. 1980. The analytic hierarchy process, New York: McGraw Hill. Revised editions, Paperback (1996, 2000), Pittsburgh: RWS Publications.

Saaty, TL. 2008. Decision making with the analytic hierarchy process, International Journal Services Sciences 1(1):83–98.

Siddayao, G.P, Valdez, SE and Fernandez, PL. 2012. Analytic hierarchy process (AHP) in spatial modeling for floodplain risk assessment. International Journal of Machine Learning and Computing, 4 (5) :450-457.

Singh, SR and Allen, DJ . 2016 . Cowpea pests and diseases. International Institute of tropical Agriculture, Ibadan, Nigeria. Manual series no. 2. pp 114. http://biblio.iita.org/documents/U79ManSinghCowpeaNothomNodev.pdf-90cde6dc3c577525f4aa0158cd088324.pdf .

Tefera, TL, Puskur, R, Hoekstra, D, Tegegne, A. 2010. Commercializing dairy and forage systems in Ethiopia: An innovation systems perspective. Working Paper17. ILRI (International Livestock Research Institute), Nairobi, Kenya, pp. 57.

Tessema, ZK, de Boer, WF, Baars, RMT, Prins, HHT. 2011. Changes in soil nutrients, vegetation structure and herbaceous biomass in response to grazing in a semi-arid savanna of Ethiopia. Journal of Arid Environment 75: 662–670.

Tzeng. GH, Lin, Lin, CW, Opricovic, S. 2005. Multi-criteria analysis of alternative-fuel buses for public transportation. Energy Policy 33: 1373–1383.