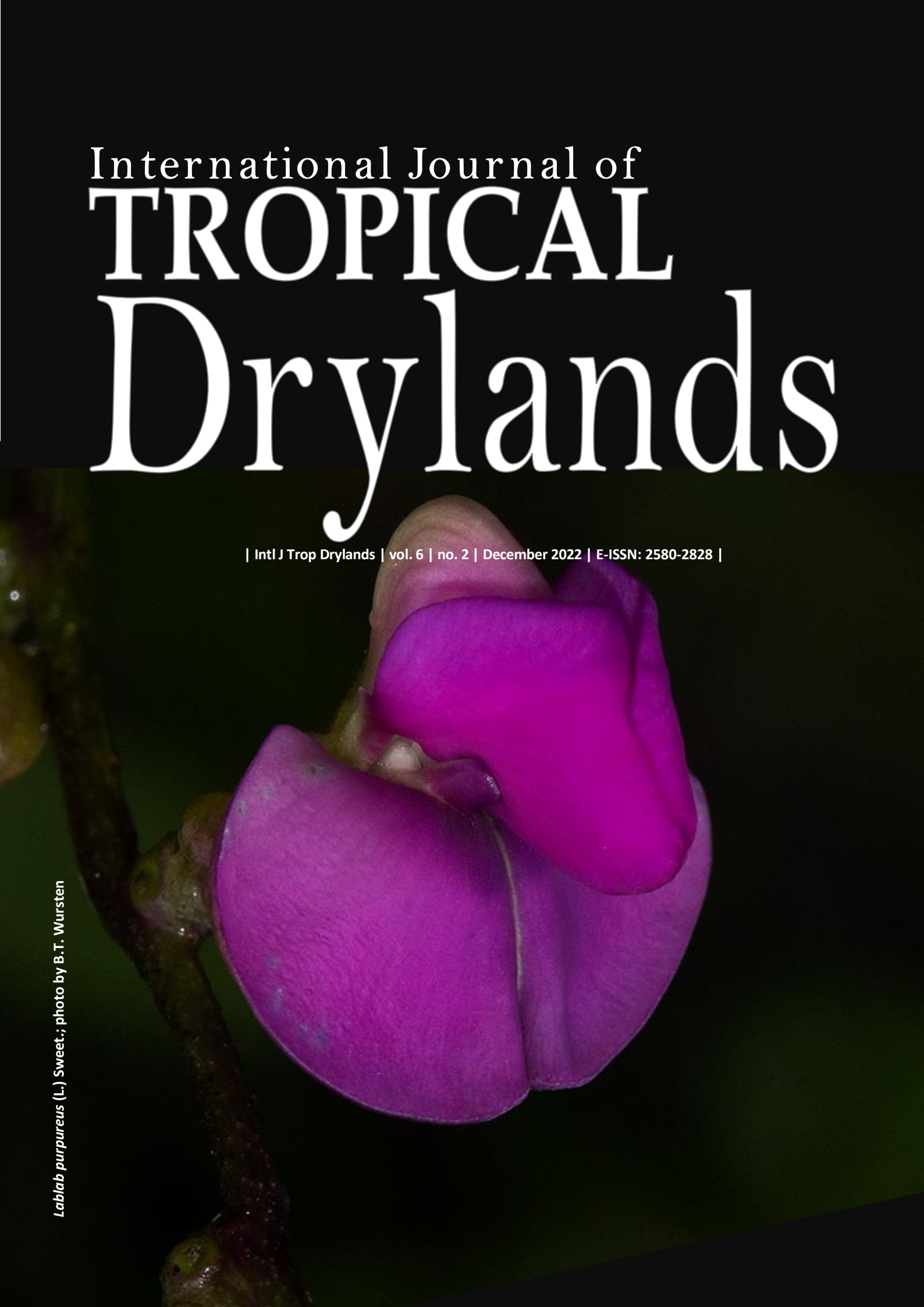
International Journal of TROPICAL Drylands

| Intl J Trop Drylands | vol. 6 | no. 2 | December 2022 | E-ISSN: 2580-2828 |



Lablab purpureus (L.) Sweet.; photo by B.T. Wursten

International Journal of
Tropical Drylands

| Intl J Trop Drylands | vol. 6 | no. 2 | December 2022 | E-ISSN: 2580-2828 |

Published semiannually **PRINTED IN INDONESIA**

E-ISSN: 2580-2828

9 772580 282121

International Journal of
Tropical Drylands

| Intl J Trop Drylands | vol. 6 | no. 2 | December 2022 |

ONLINE
http://smujo.id/td

e-ISSN
2775-6130

PUBLISHER
Society for Indonesian Biodiversity

CO-PUBLISHER
Universitas Nusa Cendana, Kupang, Indonesia

OFFICE ADDRESS
Archipelagic Dryland Center of Excellence, Universitas Nusa Cendana.
Jl. Adisucipto Penfui, Kupang 85001, East Nusa Tenggara, Indonesia. Tel.: +62-380-881580, Fax.: +62-380-881674, email: td@smujo.id, tropdrylands@gmail.com

PERIOD OF ISSUANCE
June, December

Society for Indonesian Biodiversity

Universitas Nusa Cendana Kupang, Indonesia

Published by Smujo International for The Society for Indonesian Biodiversity and Universitas Nusa Cendana Kupang, Indonesia

GUIDANCE FOR AUTHORS

Aims and Scope *International Journal of Tropical Drylands* **(Intl J Trop Drylands) (***formerly Tropical Drylands***)** encourages submission of manuscripts dealing with physical, biological and cultural aspects of dryland ecology, especially from tropical area, including human ecology on drylands, climate change, diversity and conservation, environmental management, landuse, habitat degradation and rehabilitation, geomorphological and hydrological processes, as well as soil chemistry, biology, physics, and other edaphic aspects.

Article types The journal seeks original full-length research papers, reviews, and short communication. Manuscript of original research should be written in no more than 8,000 words (including tables and picture), or proportional with articles in this publication number. Review articles will be accommodated, while, short communication should be written at least 2,000 words, except for pre-study.

Submission The journal only accepts online submission through system or email to the editors at **tropdrylands@gmail.com**. Submitted manuscripts should be the original works of the author(s). The manuscript must be accompanied by a cover letter containing the article title, the first name and last name of all the authors, a paragraph describing the claimed novelty of the findings versus current knowledge. Submission of a manuscript implies that the submitted work has not been published before (except as part of a thesis or report, or abstract); and is not being considered for publication elsewhere. When a manuscript written by a group, all authors should read and approve the final version of the submitted manuscript and its revision; and agree the submission of manuscripts for this journal. All authors should have made substantial contributions to the concept and design of the research, acquisition of the data and its analysis; drafting of the manuscript and correcting of the revision. All authors must be responsible for the quality, accuracy, and ethics of the work.

Acceptance The only articles written in English (U.S. English) are accepted for publication. Manuscripts will be reviewed by editors and invited reviewers (double blind review) according to their disciplines. Authors will generally be notified of acceptance, rejection, or need for revision within 1 to 2 months of receipt. The manuscript is rejected if the content does not in line with the journal scope, does not meet the standard quality, inappropriate format, complicated grammar, dishonesty (i.e. plagiarism, duplicate publications, fabrication of data, citations manipulation, etc.), or ignoring correspondence in three months. The primary criteria for publication are scientific quality and biodiversity significance. **Uncorrected proofs** will be sent to the corresponding author as *.doc* or *.rtf* files for checking and correcting of typographical errors. To avoid delay in publication, corrected proofs should be returned in 7 days. The accepted papers will be published online in a chronological order at any time, but printed in April and October.

Ethics Author(s) must obedient to the law and/or ethics in treating the object of research and pay attention to the legality of material sources and intellectual property rights.

Copyright If and when the manuscript is accepted for publication, the author(s) still hold the copyright and retain publishing rights without restrictions. Authors or others are allowed to multiply article as long as not for commercial purposes. For the new invention, authors are suggested to manage its patent before published.

Open access The journal is committed to free-open access that does not charge readers or their institutions for access. Readers are entitled to read, download, copy, distribute, print, search, or link to the full texts of articles, as long as not for commercial purposes. The license type is CC-BY-NC-SA.

A charge The journal is committed to free of charge for submission and publication of non-institutional funded research (waiver).

Reprints The sample journal reprint is only available by special request. Additional copies may be purchased when ordering by sending back the uncorrected proofs by email.

Manuscript preparation Manuscript is typed on A4 (210x297 mm^2) paper size, **in a single column**, single space, 10-point (10 pt) Times New Roman font. The margin text is 3 cm from the top, 2 cm from the bottom, and 1.8 cm from the left and right. Smaller lettering size can be applied in presenting table and figure (9 pt). Word processing program or additional software can be used, however, it must be PC compatible and Microsoft Word based (*.doc* or *.rtf*; **not *.docx***). **Scientific names** of species (incl. subspecies, variety, etc.) should be written in italic, except for italic sentence. Scientific name (genera, species, author), and cultivar or strain should be mentioned completely for the first time mentioning it in the body text, especially for taxonomic manuscripts. Name of genera can be shortened after first mentioning, except generating confusion. Name of the author can be eliminated after first mentioning. For example, *Rhizopus oryzae* L. UICC 524, hereinafter can be written as *R. oryzae* UICC 524. Using trivial name should be avoided, otherwise generating confusion. **Biochemical and chemical nomenclature** should follow the order of the IUPAC - IUB. For DNA sequence, it is better used Courier New font. Symbols of standard chemical and abbreviation of chemistry name can be applied for common and clear used, for example, completely written butilic hydroxyl toluene (BHT) to be BHT herein after. **Metric measurement** use IS denomination, usage other system should follow the value of equivalent with the denomination of IS first mentioning. Abbreviations set of, like g, mg, mL, etc. do not follow by dot. Minus index (m^{-2}, L^{-1}, h^{-1}) suggested to be used, except in things like "per-plant" or "per-plot". **Equation of mathematics** does not always can be written down in one column with text, in that case can be written separately. **Number** one to ten are expressed with words, except if it relates to measurement, while values above them written in number, except in early sentence. The fraction should be expressed in decimal. In the text, it should be used "%" rather than "percent". Avoid expressing ideas with complicated sentence and verbiage, and used efficient and effective sentence.

Title of the article should be written in compact, clear, and informative sentence, preferably not more than 20 words. Name of author(s) should be completely written. **Name and institution** address should also be completely written with street name and number (location), postal code, telephone number (O), facsimile number (O), and personal email address. For Indonesian universities, use local name. Manuscript written by a group, author for correspondence along with address is required. First page of the manuscript is used for writing above information.

Abstract should not be more than 200 words. **Keywords** is about five words, covering scientific and local name (if any), research theme, and special methods which used; and sorted from A to Z. All important **abbreviations** must be defined at their first mention. **Running title** is about five words. **Introduction** is about 400-600 words, covering the background and aims of the research. **Materials and Methods** should emphasize on the procedures and data analysis. **Results and Discussion** should be written as a series of connecting sentences, however, for manuscript with long discussion should be divided into subtitles. Thorough discussion represents the causal effect mainly explains for why and how the results of the research were taken place, and do not only re-express the mentioned results in the form of sentences. **Concluding** sentence should be given at the end of the discussion. **Acknowledgments** are expressed in a brief; all sources of institutional, private and corporate financial support for the work must be fully acknowledged, and any potential conflicts of interest are noted.

Figures and Tables of maximum of three pages should be clearly presented. Title of a picture is written down below the picture, while title of a table is written above the table. Colored figures can only be accepted if the information in the manuscript can lose without those images; chart is preferred to use black and white images. Author could consign any picture or photo for the front cover, although it does not print in the manuscript. All images property of others should be mentioned source. **There is no appendix**, all data or data analysis are incorporated into Results and Discussions. For broad data, it can be displayed on the website as a supplement.

References Author-year citations are required. In the text give the authors name followed by the year of publication and arrange from oldest to newest and from A to Z. In citing an article written by two authors, both of them should be mentioned, however, for three and more authors only the first author is mentioned followed by et al., for example: Saharjo and Nurhayati (2006) or (Boonkerd 2003a, b, c; Sugiyarto 2004; El-Bana and Nijs 2005; Balagadde et al. 2008; Webb et al. 2008). Extent citation as shown with word "*cit*" should be avoided. Reference to unpublished data and personal communication should not appear in the list but should be cited in the text only (e.g., Rifai MA 2007, pers. com. (personal communication); Setyawan AD 2007, unpublished data). In the reference list, the references should be listed in an alphabetical order (better, if only 20 for research papers). Names of journals should be abbreviated. Always use the standard abbreviation of a journal's name according to the **ISSN List of Title Word Abbreviations** (www.issn.org/2-22661-LTWA-online.php). The following examples are for guidance.

Journal:

Saharjo BH, Nurhayati AD. 2006. Domination and composition structure change at hemic peat natural regeneration following burning; a case study in Pelalawan, Riau Province. Biodiversitas 7: 154-158.

Book:

Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta***.** 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. www.molecularsystemsbiology.com. DOI:10.1038/msb.2008.24

THIS PAGE INTENTIONALLY LEFT BLANK

INTL J TROP DRYLANDS
Volume 6, Number 2, December 2022 E-ISSN: 2580-2828
Pages: 45-49 DOI: 10.13057/tropdrylands/t060201

Physicochemical and organoleptic properties of gebang (*Corypha utan*) starch-based analogous rice with dolichos bean (*Lablab purpureus*) flour supplementation

HERIANUS J. D. LALEL♥, I NYOMAN W. MAHAYASA, LINCE MUKKUN, ZAINAL ABIDIN, ANITA R. B. ATA
Department of Agrotechnology, Faculty of Agriculture, Universitas Nusa Cendana. Jl. Adi Sucipto Penfui, Kupang 85001, East Nusa Tenggara, Indonesia. Tel./fax.: +62-380-881580, ♥email: hlalel@yahoo.com

Manuscript received: 13 January 2022. Revision accepted: 1 July 2022.

Abstract. *Lalel HJD, Mahayasa INW, Mukkun L, Abidin Z, Ata ARB. 2022. Physicochemical and organoleptic properties of gebang (*Corypha utan*) starch-based analogous rice with dolichos bean (*Lablab purpureus*) flour supplementation. Intl J Trop Drylands 6: 45-49.* This study underpins the physicochemical and organoleptic properties of analogous rice made from gebang (*Corypha utan* Lamk) starch (GS) in combination with dolichos bean (*Lablab purpureus* L.) flour (DB). There are five combinations of the flours, i.e., (A) 100% GS, (B) 95% GS + 5% DB, (C) 90% GS + 10% DB, (D) 85% GS +15% DB, and (E) 80% GS + 20% DB. The rice was processed using an extruder. The results showed that GB supplementation increased the content of protein as well as the total ash of the analogous rice. Most of the rice has a yellowish-brown to brown color. The rice thickness ranged from 2.6 mm to 4.3 mm, while the rice length ranged from 6.5 mm to 7.0 mm. The rice's length-to-thickness ratio ranged from 1.64 to 2.47. The weight of 1000 kernels of analogous rice ranged from 17.34 g to 34.17 g, whereas the bulk density ranged from 0.46 to 0.50 g/mL. The kernels of analogous rice A, C, D, and E mostly (52-70%) had 2.4-3.3 mm thick, while 88% of Analogous rice B had 3.4-4.7 mm thick. Cooking could double the size (volume) of all analogous rice. The organoleptic test of the analogous rice gave a positive response for all products in the range of more than 4.8 to 5.5 scores (like) for the overall response of hedonic value.

Keywords: Analogous rice, dolichos bean, gebang starch, organoleptic, physicochemical

INTRODUCTION

During the last few years, Indonesia has had to import rice every year due to the increase in its demand because of insufficient domestic rice production. In addition, rice import tends to increase due to the increase in the Indonesian population. For example, in 2020, Indonesia imported the rice 214,380 tons of, or equal to 107.61 million US Dollars, mostly from Pakistan, while in 2021 (January to September), it reached 252,367 tons, or equal to 120.56 million US Dollars (Badan Pusat Statistik 2021). Its dependency of Indonesia on the import of rice leads to the low food security of the country. Therefore, some efforts are being intensively carried out to overcome this problem. One of the efforts is to find other potential sources of food that are locally available.

Gebang (*Corypha utan* Lamk) is a kind of palm tree wildly grown in most regions of Indonesia with a wide range of soil types. Gebang can grow well from 0 to 1000 m above sea level (Partomiharjo and Naiola 2009). In Kupang District, the population of gebang is mostly found in East Kupang Sub-district, with a total of about 2000 mature trees (Naiola 2008; Eagleton 2016; Lalel and Kaho 2018). The stem of mature trees aged 20 years or more have a pit rich in starch. One tree can produce about 281 kg of dry starch on average (23% of the yield), with the composition of amylose and amylopectin being 24.4% and 75.6%, respectively, which is almost similar to sago starch (Lalel et al. 2018).

Gebang starch has traditionally been used by Timorese and other local communities in Eastern Indonesia for making local food such as 'akabilan,' a kind of unfermented thin bread, and 'akasone,' a kind of dry grits. However, the use of gebang starch as a food source is sometimes negatively reported by mass media as a condition of poor economic condition, especially for those who consume these traditional foods. This negative perception arises because the pit of the gebang is also usually used as feed for pigs and remanence animals. As a raw food material, gebang starch has been used for noodles and cake products (Yamamoto et al. 2015; Lobo et al. 2017). It also has the potency to be used as the main raw material for analogous rice. The analogous rice may help fulfill the demand for rice in Indonesia, especially for people living in East Nusa Tenggara Province. It may also help increase people's appreciation of gebang starch and its potency as a food material.

Analogous rice, also known as artificial rice, is mechanically produced using starch other than rice flour with a size and shape similar to rice grain (Adelina et al. 2019). It is, therefore, possible to be fortified with other nutrient resources to increase the nutrient value of the rice. One of the important nutrients is the protein that may be acquired from other food resources, such as the seed of legumes, including the dolichos bean (*Lablab purpureus* L.). Many research works have been reported on combining starch and protein resource flours in producing analogous rice (Fitriyanto and Putra 2013; Franciska et al. 2015;

Adelina et al. 2019). It has been reported that the average production potency of the dolichos bean is 100 to 120 quintals of green pods per hectare (My Agriculture Information Bank 2018). The protein content of the dolichos bean varies from 22.4% to 31.3% (Deka and Sarkar 1990). Dolichos bean is well known and grown in Timor Island, and hence it has the potential to be used in making gebang starch-based analogous rice in this region.

Research on combining gebang starch (GS) and dolichos bean flour (DB) in making analogous rice has not been reported yet. Therefore, it is important to know the physicochemical and organoleptic properties of the analogous rice resulting from the combination of gebang starch and dolichos bean flour.

MATERIALS AND METHODS

Materials

Gebang starch was extracted from the pit of the gebang stem according to the wet method described by Lalel et al. (2018). The gebang pit was obtained from the Kupang District, East Nusa Tenggara Province of Indonesia. Dolichos bean flour was prepared from local dolichos beans purchased from the local market in Kupang City. Chemicals for analyses were purchased from several chemical providers, including Sigma-Aldrich company.

Procedures

Starch extraction was done with several steps, as briefly described next. First, the gebang pit was cut into small pieces about 5 cm long and 2 cm thick. Next, the loave of the pit was added with water at the proportion of 1:1, then crushed with a chopper machine and mixed to get a watery dough. Then, the watery dough was put on double cloth filters to pass the starch solution. Furthermore, the solution was kept for about 30 minutes to let the starch be decantated. Finally, the supernatant was poured out, and the starch was sundried for about six hours. The starch was then ready to be used for making analogous rice.

The analogous rice was prepared in five combinations of gebang starch and dolichos bean flour by using an extruder. The combinations of gebang starch (gs) and dolichos bean flour (DB) studied were A (100% GS), B (95% GS + 5% DB), C (90% GS + 10% DB), D (85% GS + 15% DB), and E (80% GS + 20% DB). Each combination was added with water (900 mL per 2.5 kg of composite flour) and glycerol monostearate (2%) to get a dough. The dough was then fed into the extruder (Berto Industries) with the cutter, auger, and screw speeds being 50.1 Hz, 30.5 Hz, and 35.1 Hz, respectively. The temperature of the extruder was set at 90^{o}C. Extrudes were dried in an oven at 60 ^{o}C for about 1 hour.

The analogous rice was analyzed for its chemical properties (water, protein, lipid, carbohydrate, and ash) by proximate analyzes according to AOAC (1984). Water content was measured using the thermogravimetric technique; protein content was estimated using the micro-Kjeldahl apparatus; lipid content was measured using a reflux system; ash content was obtained by weighing the ash of the analogous rice after heating them in a furnace at the temperature above 500°C, and the carbohydrate was calculated using the by different consideration. Furthermore, the physical properties of analogous rice recorded were color, size similarity (IRRI 1980), bulkiness (Singh et al. 2012), and expanding volume after cooking (Singh et al. 2012). The rice's color and whiteness were recorded using a Samsung digital camera (16 megapixels) fitted with constant light (2800 lx). The camera was equipped with On Color Measure software (Potatotreesoft Company) to record real-time RGB value, HSV value, Hex code, and HTML color name. RGB values were. The RGB values were then converted to CIE Lab values using Colormine software (Colormine.org). For the organoleptic test, the preference of 20 trained panelists on color, aroma, texture, and overall response to the analogous rice was recorded with 9 hedonic scores starting from extremely dislike (1) to extremely like (9) (Lim 2011).

Data analysis

Chemical and physical data were duplicated and presented on average, while organoleptic data were statistically analyzed (Analysis of variance followed by Duncan's multiple rank test at P α=0.05) using SPSS version 20.

RESULTS AND DISCUSSION

Chemical properties (proximate content)

The result of proximate analyses of analogous rice (Table 1) shows that the water content of all analogous rice was less than 10% (in the range of 5.47 to 9.05%), which meets the Indonesia Standard for Rice (maximum 14%; BSN 2008), which was dry enough to be stored. That means the rice can be safely kept for some months in dry and clean storage with a low risk of microbial deterioration. The protein content of the analogous rice was slightly lower than that of most natural rice (6.7-7.6%), as reported by Muttagi and Ravindra (2020). However, the increase of dolichos bean flour supplementation contributed to the increase of protein in the analogous rice of up to 4.7% at 20% of dolichos bean flour supplementation. This trend indicates that there is a possibility to increase the content of protein in the rice by adding more dolichos flour. The lipid content was also lower than that of natural rice (0.6-7.6%), as reported by Muttagi and Ravindra (2020). The high lipid content may decrease rice storability due to a high rancidity rate, which may easily occur. Table 1 also clearly shows that carbohydrate is the major content of the analogous rice, ranging from 85.89 to 90.26%, which may ensure it is an energy resource for consumers.

Table 1. Proximate content of the analogous rice

No	Product	Formulas (%GS+%DB)	Water (%)	Protein (%)	Lipid (%)	Ash (%)	Carbohydrate (%)
1	Rice A	100 + 0	9.05±0.21	2.18±0.09	0.14±0.07	0.75±0.11	87.88±1.02
2	Rice B	95 + 5	5.47±0.77	3.29±0.11	0.12±0.05	0.86±0.0.09	90.26±1.57
3	Rice C	90 + 10	7.00±0.42	3.87±0.16	0.12±0.08	0.92±0.07	88.09±0.67
4	Rice D	85 + 15	7.08±0.51	4.11±0.08	0.13±0.10	1.11±0.12	87.57±1.14
5	Rice E	80 + 20	8.00±0.79	4.7±0.14	0.14±0.07	1.27±0.13	85.89±1.03

Based on the chemical properties of the analogous rice, it can be noticed that the nutrition of the rice can still be improved by adding more dolichos bean flour or other food resource flour. Furthermore, adding dolichos flour itself might also improve some micronutrients (especially minerals), as indicated by the increased ash content (total minerals). Ademola and Abioye (2017) reported that the dolichos bean is rich in potassium, phosphor, calcium, magnesium, zinc, and iron. Therefore, the rice could be designed to fulfill the need for these important minerals for people in the East Nusa Tenggara Province, which is still dealing with insufficiency of some important minerals that cause stunting for the children. Recently, some studies have been conducted to find rice cultivars that have a high content of micronutrients (Indrasari and Kristamtini 2018); however, there still are some problems of mineral loss when the rice is polished because most of the micronutrients are concentrated in the very thin aleurone layers of natural rice. Therefore, the analogous rice technology can be one of the solutions to increasing the content of micronutrients in staple food.

Physical properties

Color and whiteness

Table 2 shows that the color of analogous rice from all combinations of gebang starch and dolichos bean flour ranges from yellowish-brown to brown with saturated values higher than 70%. They align with their L (lightness) values, which are more than 66 but lower than 90. As generally known that more people prefer polished white rice than non-polished rice. Nevertheless, the L values of the studied analogous rice were higher than that of the analogous rice reported by Sede et al. (2015). The appearance of the brown color of the analogous rice is mainly due to the impact of the color of raw materials and the reaction of browning during the heating of the rice that occurred in the extruder. Heating may cause a Maillard reaction on food containing reducing sugars and amino acids (Shipar 2009). Therefore, more efforts should be made to increase the rice's lightness by using some ingredients such as other whiter flour or to treat/whiten these two flour (gebang starch and dolichos bean flour) before use.

Size and bulkiness of the rice

The analogous rice thickness ranged from 2.6 mm to 4.3 mm, while the rice length ranged from 6.5 mm to 7.0 mm. The rice's length-to-thickness ratio ranged from 1.64 to 2.47 (Table 3). Based on rice length classification from FAO, these analogous rice are classified as long rice. In contrast, the overall size of the rice is classified as a medium based on the standard length-to-thickness ratio of natural rice reported by Narvarnikova et al. (2018). The thickness and length of artificial rice are lower than most natural rice, as reported by Susiyanti et al. (2020), but they are higher than those of the PR-106 rice variety (Ghadge dan Prasad 2012). The weight of 1000 kernels of analogous rice ranged from 17.34 g to 34.17 g. The weight was higher than those of some natural rice reported by Susiyanti et al. (2020). That indicates that all types of artificial rice are more compact and heavier than natural rice. All these properties of analogous rice have resulted in the value of bulk density ranging from 0.46 to 0.50 g/mL, which is almost similar to the bulk density of analogous rice developed from corn flour (Kurniasari et al. 2020). As known, bulk density is one of the important data for handling and storing materials, including food such as rice. Materials with high bulk density may need more energy for carrying or handling; on the contrary, materials with low bulk density need more space for storing, carrying, and handling. Therefore, the bulk density of this studied analogous rice may give some insights for storing, carrying, or handling consideration of the product.

The similarity of the rice

Table 4 shows that most analogous rice, except rice B, has 2.4-3.3 mm thick for more than 50 percent, with the highest value found on rice E (70%). On the other hand, Rice B has 88% similarity and falls in the range of 3.4-4.7 mm thick or mostly thicker than other analogous rice in the present study. In other words, all analogous rice is high in similarity. That indicates that the extruder may not have big problems forming and cutting those doughs to form the rice-like dimensions. It may also give the promising note that the analogous rice made from a mixture of gebang starch and dolichos bean flour could meet the standard for rice (BSN 2008). Hence, the studied analogous rice could be acceptable for consumers. However, factors influencing this phenomenon may need to be studied to increase the similarity of the analogous rice.

Swelling value after cooking

The technique to analyze the swelling value, about 10 grams of analogous rice from each treatment (rice A-E) were measured for their volume before and after being immersed in boiled water for 5 minutes and drained. Data from Table 5 show that cooking can increase the size (volume) of all analogous rice to double. The data indicate

that the analogous rice should be porous, allowing them to absorb water in a similar volume to the rice kernel. This ability may be important to be used in developing a kind of food to meet the need of people who want to fulfill their hunger quickly. One more advantage of analogous rice is it can reduce the cooking time, and even it can be treated like a cereal which is not needed to be cooked, just immersed in milk or other edible liquid, whether cold or hot. It is also can be designed to be eaten without any additional treatment. This potency may need further study to be underpinned.

Organoleptic properties

Table 6 shows that except for aroma, most organoleptic parameters have a score of around 5, which means most panelists like the color, texture, and taste of the analogous rice, even though the color of all analogous rice is a bit brown (Table 2). The preference of panelists is more noticeable on the overall response scale of all analogous rice which is statistically not significantly different within all treatments. Therefore, all analogous rice resulting from this experiment has the potency to be used as a complementary to natural rice. The intervention of this analogous rice may reduce rice import and increase food security in East Nusa Tenggara Province.

Table 2. Color and whiteness of the analogous rice

Product	HTML color name	Hex code	RGB value	HVS value	CIE lab value
Rice A	Yellowish brown	#ffe2c192	226, 193, 146	35º, 35%, 88%	L 80.09332; a* 6.90622; b* 20.9761
Rice B	Pale golden rod	#ffe4cda5	228, 205, 165	38º, 27%, 89%	L 83.37564; a* 2.04177; b* 22.8735
Rice C	Yellowish brown	#ffc6ae8c	198, 174, 140	35º, 29%, 77%	L 72.34286; a* 3.51936; b* 20.6553
Rice D	Fallow brown	#ffc19c65	193, 156, 101	35º, 47%, 75%	L 66.56115; a* 6.66441; b* 33.8944
Rice E	Yellowish brown	#ffd5b381	213, 179, 129	35º, 39%, 83%	L 74.80683; a* 5.44045; b* 30.1059

Table 3. Size and bulk density of the rice

Product	Thickness (mm)	Length (mm)	Length to thickness Ratio	Weight of 1000 kernels (g)	Bulk density (g/mL)
Rice A	2.64±0.22	6.50±0.27	2.46±0.15	23.60±1.53	0.49±0.11
Rice B	4.27±0.31	7.00±0.19	1.64±0.09	34.17±1.21	0.49±0.07
Rice C	3.03±0.17	6.56±0.21	2.16±0.11	20.87±0.97	0.50±0.09
Rice D	2.87±0.24	6.58±0.17	2.29±0.13	17.34±1.31	0.46±0.05
Rice E	2.66±0.15	6.57±0.23	2.47±0.14	20.68±0.75	0.50±0.13

Table 4. The similarity of analogous rice

Product	% kernels with < 1.7 mm thick	% kernels with 1.7-2.3 mm thick	% kernels with 2.4-3.3 mm thick	% kernels with 3.4-4.7 mm thick	% kernels with > 4.7 mm thick
Rice A	0	32	52	16	0
Rice B	0	0	4	88	8
Rice C	0	12	56	32	0
Rice D	0	16	64	20	0
Rice E	0	24	70	6	0

Table 5. The swelling value of analogous rice

Product	Swelling volume (%)
Rice A	107.02
Rice B	113.27
Rice C	103.17
Rice D	154.72
Rice E	112.27

Table 6. Hedonic value of analogous rice

Product	Color (scale)	Aroma (scale)	Texture (scale)	Taste (scale)	Overall (scale)
Rice A	5.15 [a]	4.45[a]	5.70 [b]	5.45 [b]	5.40 [a]
Rice B	5.95 [b]	4.25[a]	5.75[b]	5.25 [ab]	5.50 [a]
Rice C	5.45 [ab]	4.05[a]	4.85[a]	4.60 [a]	5.10 [a]
Rice D	5.5 [ab]	3.80[a]	4.50[a]	4.75 [a]	4.80 [a]
Rice E	5.65 [ab]	3.90[a]	5.10[ab]	5.00 [ab]	5.30 [a]

Note: Different small letters following numbers of the same column means significant difference at the level of α 5%.

It can be concluded that the analogous rice made from five combinations of gebang starch and dolichos bean flour using an extruder has all macronutrients with the maximum carbohydrate content of 90.26%, which was found in the rice B (95% GS + 5% DB) and maximum protein content (4.7%) was found in the rice E (80% GS + 20% DB) dolichos flour supplementation increased the protein content and total ash (total minerals) of the analogous rice. Most of the rice has a yellowish-brown to brown color. The rice thickness ranged from 2.6 mm to 4.3 mm, while the rice length ranged from 6.5 mm to 7.0 mm. The rice's length-to-thickness ratio ranged from 1.64 to 2.47. The weight of 1000 kernels of analogous rice ranged from 17.34 g to 34.17 g, whereas the bulk density ranged from 0.46 to 0.50 g/mL. Most analogous rice, except rice B, had 2.4-3.3 mm thick; mild and short cooking could double all analogous rice's size (volume). All panelists liked (average of the overall hedonic score was about 5 out of 9) all analogous rice made from a combination of gebang starch and dolichos bean flour.

REFERENCES

Adelina F, Estiasih T, Widyaningsih TD, Harijono. 2019. Cassava based artificial rice: A review. J Teknologi Pertanian 20 (1): 11-24. DOI: 10.21776/ub.jtp.2019.020.01.2. [Indonesian]

Ademola OA, Abioye OR. 2017. Proximate composition, mineral content and mineral safety index of *Lablab purpureus* seed flour. Intl J Sci Health Res 2 (4): 44-50.

AOAC. 1984. Official Methods of Analysis (14th Edition). Association of Official Analytical Chemists, Washington DC.

Badan Pusat Statistik. 2021. Indonesia Dalam Angka. BPS, Jakarta. [Indonesian]

Badan Standardisasi Nasional (BSN) 2008. SNI 6128:2008 Beras BPS, Jakarta. [Indonesian]

Deka RK, Sarkar CR. 1990. Nutrient composition and antinutrient factors of *Dolichos lablab* L. seeds. Food Chem 38 (4): 239-246. DOI: 10.1016/0308-8146(90)90180-C.

Eagleton GE. 2016. Review: Persistent pioneers; *Borassus* L. and *Corypha* L. in Malesia. Biodiversitas 17: 716-732. DOI: 10.13057/biodiv/d170247.

Fitriyanto M, Putra SR. 2013. Karakterisasi beras buatan (artificial rice) dari campuran tepung sagu (*Metroxylon* sp.) dan tepung kacang hijau. J Sains dan Seni Pomits 2 (1): 1-3. [Indonesian]

Franciska CY, Waluyo Y, Tamrin S, Warji, 2015. Pembuatan dan uji karakteristik fisik Beras analog dengan bahan baku tepung cassava yang diperkaya dengan protein ikan tuna. Artikel Ilmiah Teknik Pertanian Lampung 4 (2): 39-44. [Indonesian]

Ghadge PN, Prasad K. 2012. Some physical properties of rice kernels: Variety PR-106. J Food Process Technol 3: 8. DOI: 10.4172/2157-7110.1000175.

Indrasari SD, Kristamtini. 2018. Biofortifikasi mineral Fe dan Zn pada beras: Perbaikan mutu gizi bahan pangan melalui pemuliaan tanaman. J Penelitian dan Pengembangan Penelitian 37 (1): 9-16. DOI: 10.21082/jp3.v37n1.2018.p9-16. [Indonesian]

IRRI. 1980. Standard Evaluation System for Rice. International Rice Research Institute, Los Banos, Philippines.

Kurniasari I, Kusnandar F, Budijanto S. 2020. Karakteristik fisik beras analog instan berbasis tepung jagung dengan penambahan k-karagenan dan konjak. Agri Tech 40 (1): 64-73. DOI: 10.22146/agritech.47491. [Indonesian]

Lalel HJD, Kaho NPLBR. 2018. Integrasi Penggunaan Drone dan Free & Open Source Softwares (FOSS) Sistem Informasi Geografis dalam Kajian Sebaran dan Kondisi Lingkungan Pohon Gewang (*Corypha utan* Lamk.) di Kabupaten Kupang. Research Report, Universitas Nusa Cendana, Kupang. [Indonesian]

Lalel HJD, Rubak YT, Kaho NPLBR. 2018. Gebang (*Corypha utan* Lamk): The promising source of starch. Proceeding of The IAFT-SEAFAST International Conference; Science-based Ingredients: The Future for Food in Asia. Jakarta, 3-5 October 2018.

Lim J. 2011. Hedonic scaling: A review of methods and theory. Food Qual Prefer 22: 733-747. DOI: 10.1016/j.foodqual.2011.05.008.

Lobo RL, Lalel HJD, Markus JER. 2017. Karakteristik Mutu Mie Basah Substitusi Tepung Terigu dengan Pati Gewang. Laporan Penelitian. Faperta Undana, Kupang. [Indonesian]

Muttagi GC, Ravindra U. 2020. Chemical and nutritional composition of traditional rice varieties of Karnataka. J Pharmacogn Phytochem 9 (5): 2300-2309. DOI: 10.20546/ijcmas.2020.905.006.

My Agriculture Information Bank. 2018. Cultivation of Indian Bean (*Dolichos lablab*). https://agriinfo.in/cultivation-of-indian-bean-dolichos-lablab-894/ Accessed on 6 June, 2022.

Naiola E. 2008. Amylolitic microbes of nira and laru from Timor Island, East Nusa Tenggara. Biodiversitas 9 (3): 165-168. DOI: 10.13057/biodiv/d090302.

Narvarnikova, Banou J, Herak D, Verner V. 2018. Evaluation of physical properties of rice used in traditional Kyrgyz Cuisine. Food Sci Nutr 6: 1778-1787. DOI: 10.1002/fsn3.746.

Partomiharjo T, Naiola BP. 2009. Ekologi dan peresebaran gewang (*Corypha utan* Lamk.) di Savana Timor, Nusa Tenggara Timur. Berita Biologi 9 (5): 637-647. [Indonesian]

Sede VJ, Mamuaja CF, Djarkasi GSS. 2015. Kajian sifat fisik kimia beras analog pati sagu baruk modifikasi HMT (Heat Moisture Treatment) dengan penambahan tepung komposit. J Ilmu dan Teknologi Pangan 3 (2): 24-35. [Indonesian]

Shipar AH. 2009. A General Review on Maillard Reactions in Foods. [Thesis]. Toronto Institute of Pharmaceutical Technology, Toronto.

Singh AK, Singh PK, Nandan R, Rao M. 2012. Grain quality and cooking properties of rice germplasm. Ann Pl Soil Res 14 (1): 52-57.

Susiyanti, Rusmana, Maryani Y, Sjaifuddin, Krisdianto N, Syabana MA. 2020. The physicochemical properties of several Indonesian rice varieties. Biotropia 27 (1): 41-50. DOI: 10.11598/btb.2020.27.1.1030. [Indonesian]

Yamamoto Y, Pasolon YB, Rembon FS. 2015. Estimation of Starch Productivity and Quality of Starch. Accumulating Palms in The Tropics. Research Report. Kochi University, Japan.

INTL J TROP DRYLANDS
Volume 6, Number 2, December 2022 E-ISSN: 2580-2828
Pages: 56-62 DOI: 10.13057/tropdrylands/t060202

Soil quality assessment on coffee (*Coffea* spp.) farms in Pigtauranan, Bukidnon, Philippines

JEWEL MARIE S. FRANCISCO[1,2,♥], JOHN REY N. LABAJO[2,3], RAUL M. EBUÑA[2]
[1] Department of Agriculture, Pangantucan Bukidnon Community College. Pangantucan, Bukidnon, Philippines.
Tel./fax.: +63-159281859, ♥email: fjewelmarie@gmail.com.
[2]Department of Soil Science, College of Agriculture, Central Mindanao University. University Town, Musuan, Maramag, Bukidnon, Philippines
[3]Soil and Plant Analysis Laboratory, Central Mindanao University. University Town, Musuan, Maramag, Bukidnon, Philippines

Manuscript received: 24 August 2022. Revision accepted: 28 September 2022.

Abstract. *Francisco JMS, Labajo JRN, Ebuna RM. 2022. Soil quality assessment on coffee (*Coffea *spp.) farms in Pigtauranan, Bukidnon, Philippines. Intl J Trop Drylands 6: 56-62.* A study was conducted from September to March 2019 with the following objectives: (i) to determine the physical and chemical properties of soil grown with coffee, (ii) to generate a soil nutrient map of the coffee farm; and (iii) to provide fertilizer recommendations based on the result of analysis of chemical properties. The following criteria for the selection of farm sites were: (i) 1-2 hectares of coffee farm area, (ii) 3-5 years of land use for coffee production; and (iii) the variety of the coffee grown is Robusta (*Coffea canephora* Pierre ex A.Froehner). Twenty-two (22) farms fit the criteria, and a survey questionnaire was disseminated to gather information. Soil samples were collected, and each was replicated and analyzed at the Soil and Plant Analysis Laboratory CMU. The coffee farms were identified as mostly medium acidic in their pH ranging from 5.6 to 6, marginal in organic matter (2.1 to 3.5%), very deficient in their extractable phosphorus (<9.0 mg dm^{-3}), and very high in exchangeable potassium (167.70 to 245.70 mg dm^{-3}). Most coffee farms were clayey soil texture, the water holding capacity was mostly 50-59%, and most bulk densities were categorized as ideal bulk density with values ranging from (1.0 to 1.3 Mg m^{-3}). The recommended rate of fertilizer were (0.030 to 0.115 g/tree) for Nitrogen, (0.165 to 0.500 g/tree) for Phosphorus, and (0 to 0.090 g/tree) for Potassium. The fertilizer rate of 16-20-0 and 18-46-0, and 0-0-60 will be used to satisfy the nutrient deficiency in the soil, and it is highly recommended to follow the correct application of fertilizer and apply an organic fertilizer to obtain good productivity and higher yield for the coffee farms, though this still needs further studies.

Keywords: Assessment, Bukidnon, *Coffea*, Pangantucan, physical-chemical properties, soil fertility mapping

INTRODUCTION

Coffee is one of the most important commercial crop-plant and the most widely traded commodity in the world. After cocoa, coffee is the second most important agricultural product for export (Núñez et al. 2011). The genus Coffea has several species of coffee plants. Still, the two most commonly grown species are *Coffea arabica* L. or the Arabica coffee and *Coffea canephora* Pierre ex A.Froehner or the Robusta coffee (Nelson 2011). Coffee is the most important non-alcoholic beverage in the world trade (Nair 2010). Aside from other products, many Bukidnon coffee brands are produced in the province's different municipalities.

Furthermore, the mission of the DTI concerning the coffee industry is to increase productivity and make it self-sufficient and globally competitive. To date, Bukidnon has 100 coffee farmers; most of them are indigenous community members. Bukidnon province has some 2,000 hectares of cultivated land for coffee, mostly in the highlands. In Bukidnon, the dominant coffee variety is Robusta, followed by Arabica (Sablad and Enerio 2017).

Soil plays an important role in our natural resources because it can produce food and fiber for humans. It maintains terrestrial ecosystems and serves as plant growth, a sink for heat, water, and chemicals, and a filter for water. In addition, it is the biological medium for the decomposition of wastes. Soil quality is defined as a specific kind of soil's capacity to sustain plant productivity. It comprises soil's physical, chemical, and biological properties (Zhan-Feng et al. 2006). Coffee trees are tolerated in a wide range, provided with deep and porous soils and well balanced for their texture. The ideal coffee can be grown in a fertile volcanic red earth, deep sandy loam, or lateritic soil (Titus and Pereira 2017). Coffee trees perform well in organic matter rich soil, producing a better leaf area to fruit ratio and better quality. Ideally, coffee is grown in moist, fertile, well-drained soil under a shaded canopy that receives a healthy dose of sunlight daily (DaMatta 2004; Mighty 2015). Those containing nitrogen and potassium are most predominant in the bean, usually followed by calcium, magnesium, phosphorus, and sulfur. The right balance of nutrients found in soil with good soil management improves bean quality. Cooler temperatures or higher altitudes produce bigger and better beans because it leads to slower photosynthesis, allowing the plant to metabolize nutrients gradually (Aprile 2015).

The health of the soil is the primary concern to farmers because their livelihoods depend on well-managed agriculture. However, one of the farmer's problems is the poor bean type which will lead to low coffee yield affected by low nutrient availability, not being well managed and

poor knowledge about the kind of soil or the ideal soil quality of the coffee farms. The main reservoir of mineral nutrients for plants is the soil. Therefore, good production needs good soil nutrients and fertility depending on a crop. Complex interactions of biological, chemical, and physical quantities take place in the soil in which all of these components and properties are included in the concept of soil quality. The chemical properties of the soil are the pH, organic matter, and cation exchange capacity, which are important factors in determining how well the crop will grow. The good quality of the soil and availability of nutrients in the soil requires special attention from the grower because it affects the bean size. Objectives of the Study: Evaluating the soil health in coffee farms since the soil quality cannot be measured directly, assessing the soil quality of the farms grown with coffee crops is important to measure and analyze. Specifically, the study aimed to answer the following objectives: (i) to determine the physical and chemical properties of some soil grown to coffee, (ii) to generate a soil nutrient map of the coffee farm; and (iii) to provide fertilizer recommendation to the soil grown to coffee based on the result of analysis of the soil pH, organic matter content, extractable phosphorus, and exchangeable potassium.

MATERIALS AND METHODS

Study area

The study was focused only on the assessment of physical and chemical properties of soil-grown coffee those with 1-2 hectares of coffee farm area, 3-5 years of land use for coffee production; and the variety of the coffee grown is Robusta (*C. canephora*) in Barangay Pigtauranan, Pangantucan, Bukidnon, Philippines.

Survey and farm selection procedure

A survey was conducted on the selected farms grown coffee (Coffea spp.) in Barangay Pigtauranan, Pangantucan, Bukidnon, Philippines (Figure 1). To ensure a manageable number of surveyed farms, the farmers that were selected possessed the following criteria: (i) 1-2 hectares of coffee farm area, (ii) 3-5 years of land use for coffee production; and (iii) the variety of the coffee grown is Robusta (*C. canephora*).

Collection, preparation, and analysis of soil sample

The owner of the farms was interviewed first using the questionnaire that was given. After the interview, the soil samples to a depth of 40-60 cm were collected from the farmer's field covered in the survey. The collected samples were air dried and pulverized using a screen or 2 mm sieve and then it was stored in plastic jars for the determination of the physical and chemical properties of the soil. Analysis was performed at the Soil and Plant Analysis Laboratory, Department of Soil Science, College of Agriculture, Central Mindanao University, University Town, Musuan, Maramag, Bukidnon, Philippines. Methods used in the Analyses of Soil's Physical and Chemical properties are presented in Table 2. The sampled area is presented in Figure 2.

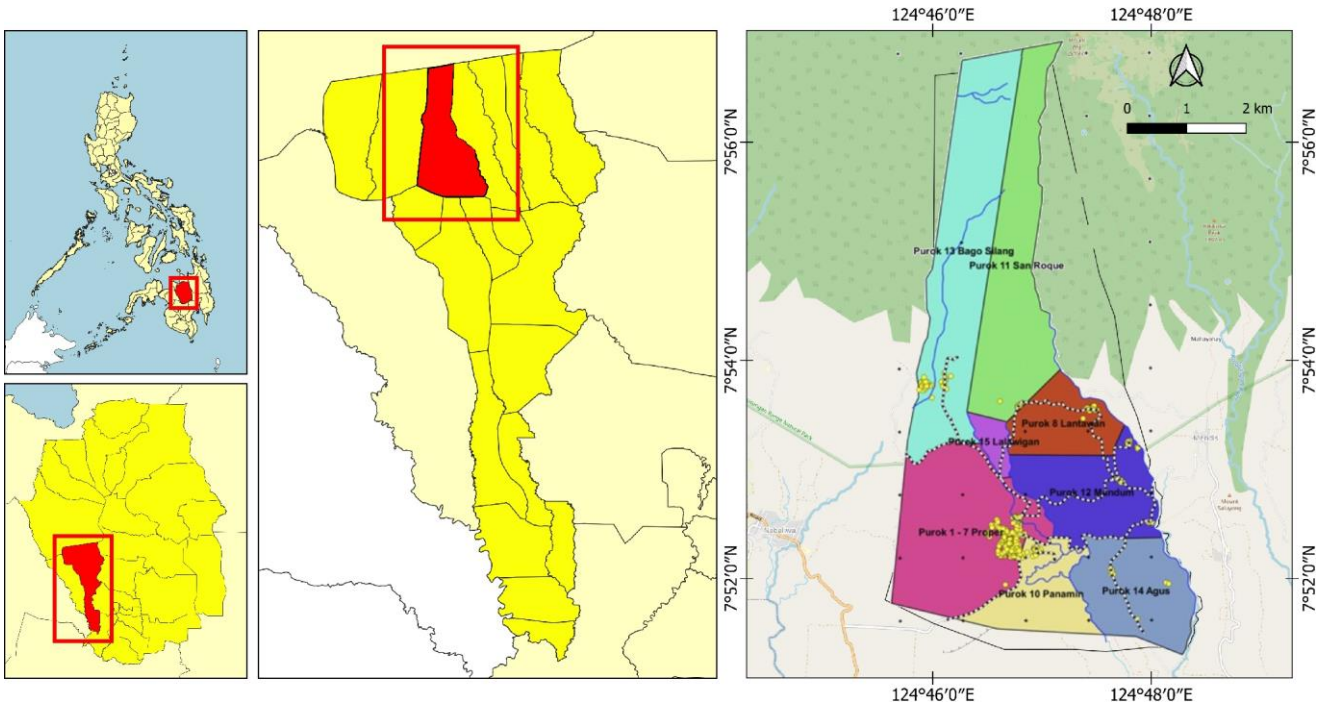


Figure 1. Location map of the study Barangay Pigtauranan, Pangantucan, Bukidnon, Philippines

Table 1. Soil test values and a nutrient recommendation rate of coffee (kg/tree)

Category	Recommended Rate (kg/tree)												
	Organic matter, (%) Nitrogen, kg/tree				Phosphorus (mg dm^{-3}) P_2O_5, kg/tree					Potassium (mg dm^{-3}) K_2O, kg/tree			
Soil test values	0-2	2.1-3.5	3.6-4.5	>4.5	0.9	10-15	16-22	23-30	>30	0-35	36-55	56-75	>75
New plant	0.003	0.002	0.001	0.000	0.004	0.003	0.002	0.001	0	0.003	0.002	0.001	0
1 year old	0.04	0.025	0.015	0.010	0.115	0.070	0.040	0.010	0	0.045	0.030	0.012	0
2 year old	0.055	0.035	0.020	0.015	0.125	0.075	0.045	0.020	0	0.048	0.032	0.018	0
3 year old	0.070	0.040	0.025	0.020	0.135	0.085	0.050	0.025	0	0.060	0.040	0.270	0
4 year old	0.085	0.050	0.030	0.025	0.500	0.095	0.055	0.025	0	0.075	0.050	0.030	0
5 year old	0.115	0.070	0.045	0.030	0.165	0.105	0.060	0.030	0	0.090	0.060	0.045	0
6-10 years old	0.160	0.100	0.070	0.050	0.130	0.080	0.045	0.020	0	0.390	0.120	0.060	0
11-15 years old	0.230	0.145	0.090	0.070	0.145	0.090	0.050	0.025	0	0.450	0.300	0.090	0
>15 years old	0.165	0.100	0.070	0.050	0.100	0.065	0.040	0.020	0	0.300	0.200	0.060	0

Note: PCARRD (1991)

Table 2. Methods used in the analysis of the physical and chemical properties of soil

Property	Methods of analysis	Reference
Physical properties		
Soil texture	Pipette method	PCARRD (1991)
Water holding capacity	Wire gauze method	Lal and Shukla (2004)
Bulk density	Core method	Blake (1965)
Chemical properties		
Soil pH	Potentiometric method (1:5 soil water ratio)	Biddle (1997)
Organic matter content	Walkley-Black method	FAO GLOSOLAN (2020)
Extractable phosphorus	BrayP_2 (o.1N HCl + 0.03N NH_4F)	Landon (1984)
Exchangeable potassium	1N NH_4OAc extraction/Flame photometer	Landon (1984)
Lime requirement	Veitch Method	Hoskins (1997)

Procedures

Preparation of soil physical and chemical fertility map

Generating the soil fertility map of each coffee farm in Pigtauranan, Pangantucan, Bukidnon was the first to be categorized using the soil test values for pH, exchangeable phosphorus, and extractable potassium (Hoskins 1997), and soil organic matter soil test values of PCARRD (1991) and was assigned with designated color for identification as presented in Figure 2. The soil fertility map of pH, organic matter content, extractable phosphorus, and exchangeable potassium was mapped and generated using ArcGIS software by Esri.

Computation for fertilizer and lime recommendations

Fertilizer recommendations are computed using the nutrient recommendation rate developed by PCARRD (1991) for coffee in the Philippines, presented in Table 1. Soil test values are the result of the conducted soil chemical analysis of OM, extractable phosphorus, and exchangeable potassium and matched with the recommended rate of fertilizer per coffee tree at a different age to derive the amount of fertilizer recommended per tree. The lime recommendation was based on the result of the Veitch method (Hoskins 1997) with the amount of lime on the x-axis and pH on the y-axis and was computed based on the desired pH for coffee which is 5.5.

RESULTS AND DISCUSSION

Soil chemical properties

The soil pH value of coffee farms in Barangay Pigtauranan, Pangantucan, Bukidnon is shown in Table 3. Six (6) coffee farms (27.27%) were characterized as strongly acidic, having a soil pH value of 5.1 to 5.5. Twelve (12) coffee farms (54.54%) were categorized as medium acidic, having a soil pH value of 5.6 to 6.0. Meanwhile, there were only three (3) coffee farms (13.64%) identified as slightly acidic, where the pH values ranged from 6.1-6.9, and only one (1) coffee farm was categorized as neutral, having a soil pH value of 7.0 (4.54%). Therefore, it was observed that most of the coffee farms in Barangay Pigtauranan fell on medium acidic, where according to (PCARRD 1991), the soil pH requirement of coffee ranges from 5.5-to 7.0. Based on the result, most coffee farms were suited for their production.

The percent organic matter of the coffee farms was identified as deficient in the organic matter having a value of <2.0% or five (5) of the coffee farms (22.73%). Ten (10) coffee farms (45.45%) fell on a marginal amount of organic matter having a value of 2.1 to 3.5%, five (5) categorized (22.73%) on the adequate amount with a value of 3.6 to 4.5%, and only two (2) had a highly adequate amount of organic matter having a value of >4.5% (9.09%). Based on the results, most of the coffee farms in Barangay

Pigtauranan were categorized as marginal because most farmers applied organic fertilizer to their coffee farms.

Table 3 also shows that all twenty-two (22) coffee were deficient in extractable phosphorus, with twenty-one (21) coffee farms (95.45%) recognized as very deficient in phosphorus content having <9.0 mg dm^{-3} and one (1) or 4.55% with deficient status which is 10-15 mg dm^{-3} (PCARRD 1991). Based on the results, extractable phosphorus of the coffee farms was very low because only a few farmers applied complete fertilizer and phosphorus-containing fertilizer to their farms; thus, farms were recommended to apply phosphorus-containing fertilizer to satisfy the said nutrient in the soil. According to Sage (2014), phosphorus will provide the coffee trees' roots and bearing wood development, early berry maturity, and increase the bean's density.

The exchangeable potassium content of coffee was Six (6) coffee farms (27.27%) identified as low in exchangeable potassium with a value of <74.10 mg dm^{-3}, as well as in the medium category having a value of 0.19-0.29 cmol kg-1. On the other hand, two (2) of the coffee farms (9.09%) were categorized as high in exchangeable potassium with a value of 0.29-0.38 mg dm^{-3}, and eight (8) or 36.36% of the farms fell into the category of very high in exchangeable potassium, with a value of >148.20 mg dm^{-3} (PCARRD 1991). Based on the results, most coffee farms in Barangay Pigtauranan had high exchangeable potassium. In contrast, other farms were still recommended to apply potassium-containing fertilizer to obtain enough potassium for berry development and for the crop to grow efficiently (Sage 2014). This is because; most farmers used potassium-containing fertilizer on their farms, such as muriate of potash. The result of the soil's chemical properties was presented in the fertility map presented in Figure 2.

The productivity of coffee production is affected by soil and environmental factors, in which soil pH is the biggest factor in determining the availability of the soil's chemical nutrients. Strongly acidic soil conditions may limit the availability of phosphorus and potassium; thus, excessive application of inorganic fertilizer without the knowledge of the right amount and the right timing of the application may contribute to soil acidification. Between July 2008 and June 2009, (Saroj and Dilip 2014) worked on the investigation of physicochemical factors such as pH, specific conductivity, chloride, total alkalinity, calcium, magnesium nitrate, sulfate, phosphate sodium, and potassium. Several characteristics fluctuated for the research year. The soil was alkaline throughout the research year, according to the findings. The quality of the soil determines an ecosystem's productivity. Some metrics were over the allowed range, while others were below it, affecting pond soil quality and productivity. Several factors influence the number of plant nutrients required by coffee trees. These include seasonal change, terrain, soil type, and dominant cultural techniques; the amount and distribution of rainfall; the species and number of other plants planted in combination with the coffee trees; because it impacts bean size (grade), bean quality, and the overall productivity of the crop, which determines marketability, proper coffee nutrition demands specific attention from the grower. Nutrients are given to replace those lost due to tissue formation, yields, leaching, and substances that are difficult to obtain by roots (Melke and Ittana 2015).

Soil physical properties

Table 3 shows the bulk density of selected coffee farms in Pigtauranan, Pangantucan, Bukidnon. Five (5) of the farms were categorized as very loose, which has a value of <1.0 Mg m^{-3} (22.73%). There were sixteen (16) categorized as ideal soil (72.73%), with a value of 1.0-1.3 Mg m^{-3}. Only one (1) farm falls on compacted bulk density (4.54%), with a value of >1.3 Mg m^{-3}, which is expected to restrict root growth, and poor movement of air and water through the soil. Due to the very loose and compact soil, it was not expected to obtain a higher yield for the farm. In a similar study conducted by Labajo and Pabiona (2022), most of the soil in Mt. Nebo, Valencia City, Bukidnon planted with sugarcane has bulk density values ranging from 1.0 Mg m^{-3} to 1.3 Mg m^{-3}, which is the ideal bulk density for growing crops, because it is not too loose and compacted.

The soil texture of the selected coffee farms. Twenty-one (21) among the farms were classified as clayey (95.45%), while only one (1) or 4.55% coffee farm was identified as clay loam. Most coffee farms were identified as clayey soil, in which coffee soil needs deep and porous soils and is well balanced for their texture. Since it influences nutrient and water retention, the soil texture will also affect the yield (Titus and Pereira 2017). Clayey soil texture holds very much water when wet and is highly compacted when dry. Application of organic manures and organic fertilizer increase soil aggregation and improves soil structure, thus influencing water holding capacity

The water holding capacity of selected coffee farms, out of twenty-two farmers, eleven (11) or 50% of which can hold water for about 50-59%, in which organisms suffered from dryness. The other eleven (11) farms (50%) can hold water for about 60-80%, which is the normal field soil that corresponds to optimal biological activity for water holding capacity.

In a similar study conducted in Krakow, Poland, by Kormanek et al. (2015), the results demonstrate that most of the growth characteristics of the studied seedlings were considerably impacted by the change in dry bulk density soil. The length and dry bulk of the root system showed particularly strong negative relationships. It was shown that the dry bulk density variant substantially impacted all of the growth characteristics of Scots pine seedlings and a few characteristics of European beech. Obviously, an increase in soil bulk density also contributed to a decline in the quality of European beech seedlings. Reichert et al. (2009) also concluded that the bulk density is highly correlated to the clay content, and soil ecological properties are affected before compaction restricts plant growth and yield.

Table 3. Physical and chemical properties of the soil in the selected coffee farms in Pigtauranan, Pangantucan, Bukidnon, Philippines

Farm code	Soil pH	% OM	Exchangeable phosphorus mg dm^{-3}	Extractable potassium mg dm^{-3}	Bulk density mg m^{-3}	Water holding capacity, %	Soil texture class
F1	5.92	2.19	3.26	245.70	1.22	53.17	Clayey
F2	5.70	5.81	6.87	62.40	0.93	68.60	Clayey
F3	5.46	2.36	2.57	167.70	0.83	54.95	Clayey
F4	5.28	4.88	13.29	89.70	1.09	58.71	Clayey
F5	5.48	4.21	6.93	136.50	1.12	59.33	Clayey
F6	5.63	1.85	1.39	183.30	1.19	60.35	Clayey
F7	5.60	3.28	2.17	101.40	1.11	61.20	Clayey
F8	5.45	2.69	2.43	187.20	1.12	58.84	Clayey
F9	5.32	3.62	3.83	105.30	0.97	65.38	Clayey
F10	6.31	4.12	6.35	214.50	0.97	72.38	Clay Loam
F11	6.28	2.78	6.59	237.90	1.19	60.05	Clayey
F12	5.90	4.38	2.19	191.10	1.25	50.63	Clayey
F13	6.00	1.85	0.85	136.50	0.93	66.56	Clayey
F14	5.64	2.69	1.24	54.60	1.07	62.25	Clayey
F15	5.80	0.76	0.99	50.70	1.20	55.30	Clayey
F16	5.74	1.60	1.06	245.70	1.18	70.77	Clayey
F17	5.49	2.61	0.96	93.60	1.06	57.13	Clayey
F18	5.87	3.62	1.66	78.00	1.11	65.68	Clayey
F19	5.60	1.60	3.37	74.10	1.05	66.68	Clayey
F20	6.02	2.19	1.47	39.00	1.15	54.58	Clayey
F21	7.04	3.53	1.85	31.20	1.13	50.16	Clayey
F22	5.66	3.45	2.09	35.10	1.31	54.28	Clayey

Table 4. Fertilizer recommendation of coffee farms in Pigtauranan, Pangantucan, Bukidnon, Philippines

Farmers code	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Lime recommendation (mg ha^{-1})
F1	140	400	200	6.28
F2	110	300	200	6.27
F3	140	200	200	6.46
F4	80	400	200	4.71
F5	80	200	200	1.84
F6	80	400	200	3.96
F7	140	200	200	1.87
F8	80	400	200	3.57
F9	200	200	200	4.51
F10	110	500	200	3.68
F11	110	300	200	1.64
F12	110	400	170	6.96
F13	110	400	200	4.64
F14	140	400	200	3.29
F15	170	400	200	5.99
F16	80	400	200	5.95
F17	170	300	170	3.62
F18	140	400	200	4.46
F19	110	400	200	8.68
F20	110	400	200	4.79
F21	80	400	200	2.14
F22	110	400	200	4.34

Fertilizer recommendation

The fertilizer recommendation of coffee farms in Barangay Pigtauranan, Pangantucan, Bukidnon is presented in Table 4. There were fourteen (14) different sets of recommendation rates distributed on different coffee farms. The nitrogen recommendation ranges from 0.03-0.115 kg/tree, and the phosphorus recommendation ranges from 0.165-0.500 kg/tree, which needs 0.825 kg/tree of ammonium phosphate (16-20-0), while other farms are recommended to use the 0.207-1.090 kg/tree of diammonium phosphate (18-46-0) to satisfy the recommended rate in a lower amount. The potassium recommendation ranges from 0-0.09 kg/tree, which needs to apply 0.083-0.150 kg/tree of muriate of potash (0-0-60). The lime recommendation was computed based on the result of the Veitch method analysis of soil with the amount of lime on the x-axis and pH on the y-axis on the desired pH for coffee which is 5.5. Therefore, twelve (22) sets of lime recommendations were distributed on different coffee farms in Pigtauranan, Pangantucan, Bukidnon, Philippines.

A similar study was conducted in Oromia Region, Ethiopia, by Chimdi et al. (2012); soil acidity is one of the major limiting factors to acid-sensitive crop production in the western areas of the Oromia Region, Ethiopia. Soil acidity is one of the main problems restricting the cultivation of acid-sensitive crops. Increasing lime rates for both lime particle sizes raised soil pH, and exchangeable bases reduces the magnitude of soil acidity, exchangeable acidity, and Al saturation. The acid saturation percentage significantly decreased when 10 Mg ha-1 of lime was given to the soil. This resulted in lower soil acidity, which raised the pH and accessible P in the soils.

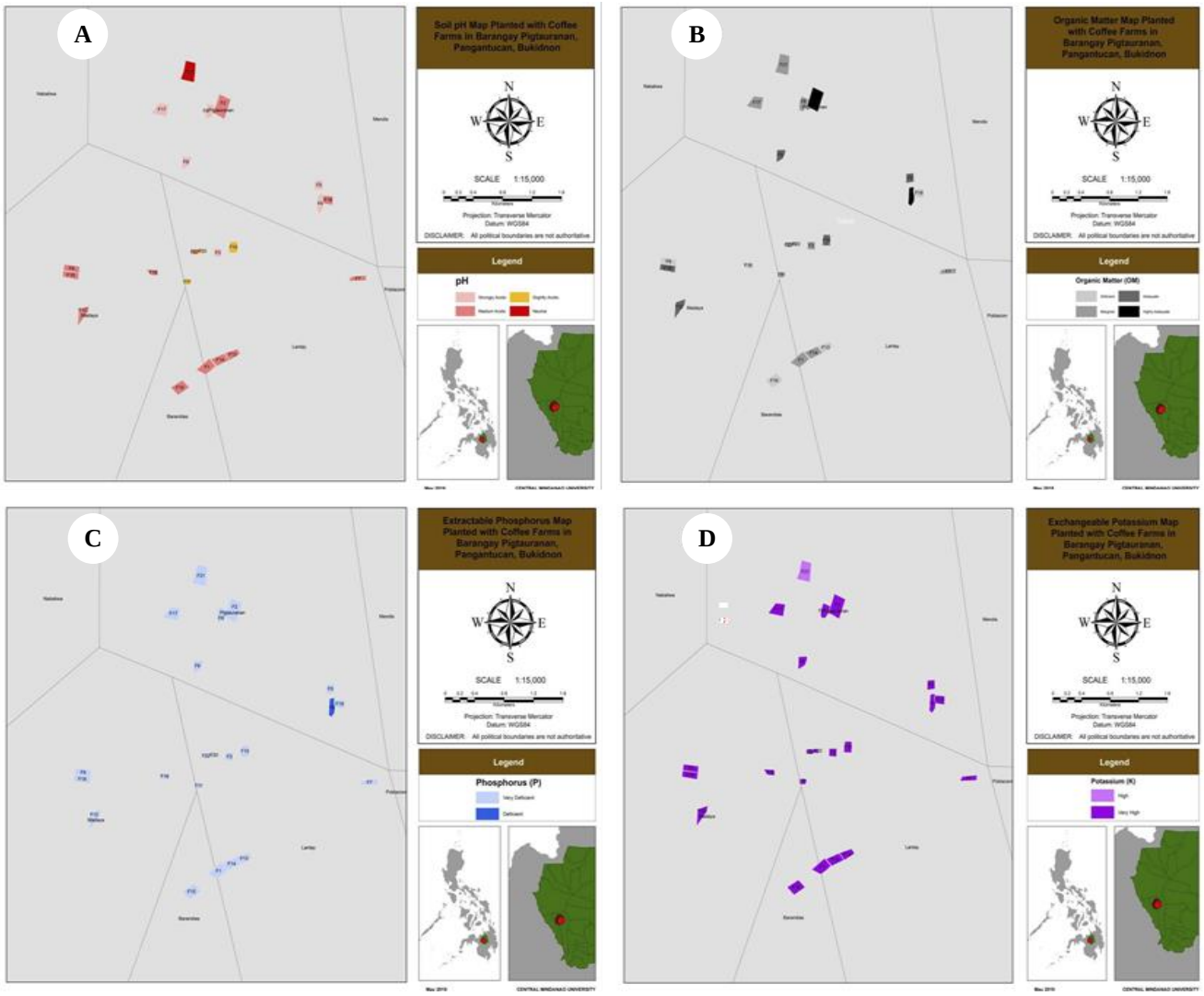


Figure 2. Soil chemical fertility map of selected coffee farms in Pigtauranan, Pangantucan, Bukidnon, Philippines: A. Soil pH, B. Organic matter content, C. Exchangeable phosphorus, D. Extractable potassium

In conclusion the soil quality of the farms grown coffee crops must be measured and analyzed since the soil quality cannot be measured directly. The soil chemical properties of the coffee farms were analyzed, such as pH, in which, among the 22 farms, most of them (54.54%) were categorized as medium acidic, having a value of 5.6-6.0. The organic matter content of coffee farms was mostly categorized as marginal, with a range of 2.1-3.5 (45.45%). The extractable phosphorus of the coffee farms was very deficient with a value of <9.0 mg dm^{-3} (95.45%), and the exchangeable potassium was categorized as very high with a value of >148.20 mg dm^{-3} (36.36%). The soil's physical properties in most coffee farms were categorized as clayey in soil texture (95.45%), holding the water with a capacity of 50-59% (50%), then the bulk density was categorized as ideal soil (72.73%) which have a value of 1.0-1.3 Mg m^{-3}. There were 14 different sets of recommendation rates distributed in different coffee farms derived from the analysis. The NPK recommendation was 0.03-0.115 kg/tree N, 0.165-0.500 kg/tree P, and 0-0.09 kg/tree K. It is recommended that selected coffee farms need to apply fertilizer to satisfy the nutrient deficiency in the soil; however, it is highly recommended to apply organic fertilizer since based on the analysis of the correlation between soil parameters and the yield, organic matter content is the only factor that can sustain good productivity and higher yield for the coffee farms, which still needs further studies.

ACKNOWLEDGEMENTS

To all the people who eagerly helped to make this study possible, the author would like to express her gratitude and thanks, first and foremost, to her parents, who always love and support her financially and emotionally. Especially to her father, Marcial C. Francisco, helped her climb those rocky mountains and cross the rocky rivers during the soil sampling. To her mother, Rosa Rosita S. Francisco, who never gets tired of advising and inspiring her. To her

sisters, cousins, Secadron, and Francisco's family, who sincerely motivates her every day. To her trustworthy adviser, Prof. Raul M. Ebuña, the author would wholeheartedly thank him for the patience, advice, knowledge, and guidance he shared. To her panel members, Ms. Cyd Cherisse U. Gayonan and Dr. Jessie G. Suson, for the concern and assistance they provided the author. To Dr. Myrna G. Pabiona for generously sharing her knowledge in helping the author with her laboratory work. To all the faculty of the Department of Soil Science, Central Mindanao University, Philippines, as well as the staff of the SPAL, the author would like to thank their guidance and assistance. Finally, beyond anything else, the author will never forget thanking the Heavenly Father, the source of knowledge and wisdom, who created heaven and earth, for letting this great achievement happen in the author's life.

REFERENCES

Aprile H. 2015. Coffee ground: The importance of soil health. Retrieved from www.coffeelands.crs.org.

Biddle DL. 1997. A compilation of selected methods for soil and plant chemical analysis. Department of Agriculture, University of Queensland, Australia.

Blake GR. 1965. Bulk density. In: Black CA (eds). Methods of Soil Analysis: Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling. American Society of Agronomy, Inc., Wisconsin. DOI: 10.2134/agronmonogr9.1.c30.

Chimdi A, Gebrekidan H, Kibret K, Tadesse A. 2012. Effects of liming on acidity-related chemical properties of soils of different land use systems in Western Oromia, Ethiopia. World J. Agric Sci 8 (6): 560-567. DOI: 10.5829/idosi.wjas.2012.8.6.1686.

DaMatta, F. M. 2004. Ecophysiological constraints on the production of shaded and unshaded coffee: A review. Field Crops Res 86 (2-3): 99-114. DOI: 10.1016/j.fcr.2003.09.001.

FAO, GLOSOLAN. 2020. Standard operating procedures for soil organic carbon: Walkley and Black method. GLOSOLAN's Best Practice Manual. GLOSOLAN-SOP-02. FAO, Rome.

Hoskins BR. 1997. Soil Testing Handbook for Professionals in Agriculture, Horticulture, Nutrient, and Residuals Management. 3rd ed. Maine Forestry and Agriculture Experiment Station, University of Maine, Orono, Maine, USA.

Kormanek M, Banach J, Sowa P. 2015. Effect of soil bulk density on forest tree seedlings. Intl Agrophys 29 (1): 67-74. DOI: 10.1515/intag-2015-0003.

Labajo JRN, Pabiona M. G. 2022. Physical and chemical properties of soil on selected sugarcane farms in Mt. Nebo, Valencia City, Bukidnon, Philippines. Asian J Agric 6 (2): 79-86. DOI: 10.13057/asianjagric/g060205.

Lal R, Shukla MK. 2004. Principles of Soil Physics. CRC Press, Boca Raton. DOI: 10.4324/9780203021231.

Landon JR. 1984. Tropical Soil Manual. Booker Agriculture. International Limited, London.

Melke A, Ittana F. 2015. Nutritional requirement and management of arabica coffee (*Coffea arabica* L.) in Ethiopia: National and global perspectives. Am J Exp Agric 5 (5): 400. DOI: 10.9734/AJEA/2015/12510.

Mighty MA. 2015. Site suitability and the analytic hierarchy process: How GIS analysis can improve the competitive advantage of the Jamaican coffee industry. Appl Geogr 58: 84-93. DOI: 10.1016/j.apgeog.2015.01.010.

Nair KP. 2010. The Agronomy and Economy of Important Tree Crops of the Developing World. Elsevier Insights, USA.

Nelson JS. 2011. Coffee as Fertilizer? University of Illinois Board of Trustees, USA.

Núñez PA, Pimentel A, Almonte, Sotomayor-Ramírez D, Martínez N, Pérez A, Céspedes CM. 2011. Soil fertility evaluation of coffee (*Coffea* spp.) production systems and management recommendations for the Barahona Province, Dominican Republic. J Soil Sci Plant Nutrition 11 (1): 127-140. DOI: 10.4067/S0718-95162011000100010.

Philippine Council for Agriculture and Resources Research and Development (PCARRD). (1991). Standard Methods of Analysis for Soil, Plant Tissue, Water and Fertilizer. Philippine Council for Agriculture and Resources Research, Farm Resources and Systems Research Division, Los Baños, Laguna.

Reichert JM, Suzuki LEAS, Reinert DJ, Horn R, Håkansson I. 2009. Reference bulk density and critical degree-of-compactness for no-till crop production in subtropical highly weathered soils. Soil Till Res 102 (2): 242-254. DOI: 10.1016/j.still.2008.07.002.

Sablad JO, Enerio BD. 2017. DTI to Boost Bukidnon Coffee Industry. SunStar Publishing Inc., Philippines.

Sage E. 2014. Basic plant biology: keeping the coffee plant "happy". Retrieved from: www.scanews.coffee.

Saroj M, Dilip B. 2014. Assessment of Physicochemical Characteristics of the Soil of Nagchoon Pond Khandwa. MP, India.

Titus A, Pereira G. 2017. Importance of healthy coffee soils. Retrieved from www.ecofriendlycoffee.org

Zhan-Feng L, Bo-Jie F, Gou-Hua L, Yong-Guan Z. 2006. Soil Quality: Concept, Indicators and its Assessment. Key Laboratory System, Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing.

INTL J TROP DRYLANDS
Volume 6, Number 2, December 2022 E-ISSN: 2580-2828
Pages: 63-76 DOI: 10.13057/tropdrylands/t060203

Household vulnerability and adaptive capacity on impacts of climate change and adaptability solution in Soroti District, Uganda

EDITH AMONDI OGALLO, BONIFACE N. WAMBUA♥, MIKALITSA S. MUKHOVI
Department of Geography and Environmental Studies, University of Nairobi. Nairobi, Kenya. Tel. +254-20-318262,
♥email: wambua_boniface@uonbi.ac.ke

Manuscript received: 18 August 2022. Revision accepted: 4 October 2022.

Abstract. *Ogallo EA, Wambua BN, Mukhovi MS. 2022. Household vulnerability and adaptive capacity on impacts of climate change and adaptability solution in Soroti District, Uganda. Intl J Trop Drylands 6: 63-76.* This study aimed to assess the vulnerabilities, impacts, and adaptation strategies of households in the Soroti District, Uganda. The data from household surveys, interviews with key informants, and focused group discussions were used to obtain data on climate change and variability impacts, adaptation strategies, and vulnerability. The rainfall and temperature data from Soroti meteorological station was also used to determine climate variability and change. The Microsoft Excel 2007 and Statistical Package for Social Science (SPSS) 16 program entered all the quantitative data. The results were then represented in tables, graphs, and charts. The temperature and rainfall analysis show that the area's climate has recently changed. These scenarios were confirmed by people's perception, along with increased drought, floods, and incidences of diseases and pests. That could have serious implications for agriculture, the major source of livelihood within the district. For instance, the delay of the 2013 March-April-May (MAM) rainfall onset and extended dry spell between the seasons led to subsequent poor harvests and serious crop failure. Other major impacts of climate change and variability on livelihoods include low fish catches, decreased water availability, lack of animal feeds, and decline in soil fertility. Although the entire district is vulnerable to the impact of climate change and variability, vulnerability is heightened for women, children, the poor, and the less educated. However, the residents have adopted certain coping and adaptation strategies to deal with the climate change impacts. The current coping strategies include selling household assets, wage labor, petty trading, and reducing consumption. Adaptation strategies include shifting planting dates, off-farm jobs, planting different crops, diversifying crops, and diversifying from farm to non–farm activities. However, these strategies are insufficient due to overarching stressors such as over-dependence on rainfed agriculture, poverty, and lack of information and technology. Moreover, there is an urgent need to alleviate poverty and unemployment within the district by creating employment opportunities for the locals and enhancing the micro-financing efficiency to improve resilience and adaptation to climate change and variability. There is also a need for robust contingency planning and the relevant institutions' involvement in early warning. Local knowledge integration in climate policies also could enhance resilience and improve adaptation.

Keywords: Adaptation, Soroti District, Uganda, vulnerability

INTRODUCTION

Climate change and variability have become local phenomenon just as it is global. However, its magnitude is now being felt at almost all scales and in all regions felt and at almost all scales, with extreme events such as excessive rainfall, heat waves, drought, and dry spells affecting much of rural in the world, include Africa (Adger 2000; Dube and Phiri 2013; Loo et al. 2015; Bakari et al. 2018; Kong'ani et al. 2018; Wambui et al. 2018; Kuria et al. 2019). IPCC (2001a) signifies that scientific evidence of human-induced global warming is worse than previously estimated and unequivocal. The report states that in the last century, Africa warmed by 0.7°C and projected more for the 21st century ranging from 0.2°C (low scenario) to over 0.5°C (high scenario) per decade. Therefore, urgent action must be taken to respond to these ongoing changes. Warming is projected in all regions throughout the continent, although there is variability in the speed of change and magnitude. The anthropogenic emissions of gases (e.g., methane and carbon dioxide) increasing into the atmosphere, and a resultant enhanced greenhouse effect, are the major driving force of the accelerated global warming trend that has been observed which taken place over the last century (IPCC 2001a, 2007; Adger 2000).

Uganda's largest economy is agriculture, providing employment to 66 % of the working population and contributing up to 42% of the Gross Domestic Product (GDP) (UBOS 2011). However, the productivity and competitiveness of this sector are increasingly constrained by the temporal and spatial variability of climate (Ekere 2012). Uganda is highly susceptible to climate variability and change. The economy, as well as the well-being of its people, is dependent on rain-fed agriculture; therefore, climate change may mean increased food insecurity, soil erosion, land degradation, over-flooding leading to an outbreak of diseases like malaria, and damage to infrastructure and settlements (Twinomugisha 2005; Boon and Ahenkan 2012; Onyekuru et al. 2014). Communities located in remote areas and limited opportunity to influence the policies that affect their lives and have limited access to social services are, therefore, likely to be more vulnerable (Orindi and Eriksen 2005; Suryavanshiet al. 2012; Tambo and Abdoulaye 2013). In addition, Uganda has been

experiencing an intensity of extreme weather events and an increase in the frequency with serious socio-economic consequences. Uganda experienced seven drought episodes in the 1991–2000 decade alone. Extreme droughts negatively affected hydropower production, agriculture, water resources, and the overall economy (Wasige 2009). The 1997/98 El Nino is recorded to have inflicted heavy losses. For instance, crops were destroyed, swept bridges, and water-borne diseases such as cholera and other flood-related diseases were experienced. As of December 1998, it is estimated that floods and landslides killed 100 people, and 150,000 were displaced from their homes (Wasige 2009). The higher-than-normal rains between July and October 2007 caused flooding in eastern Uganda, where Amuria, Katakwi, and Soroti districts were the most affected. Water inundated many areas, leading to heavy loss of first-season crops, which would be harvested in July/August (UNEP 2009). In February 2010, Eastern Uganda experienced water-logging, landslides, and flooding due to heavy rains. A report by the International Committee of the Red Cross (ICRC) indicated that the floods and landslides resulted in displaced people, destruction of property, and deaths. The roads were inaccessible, and food crops were destroyed. The most affected districts include Soroti, Amuria, Pallisa, Mbale, Moroto, Bukwo, Katakwi, and Budaka (ICRC 2010).

Soroti District is located in the Teso sub-region of eastern Uganda, which is considered prone to climate hazards, like the recent ones being 2007 floods and drought that hit the same area in 2009. Because of these serial shocks, the sub-region continues to be one of the least developed areas in the country (Nanduddu 2007). This study's findings will guide policy-makers and the local community to build resilience and make the social-ecological system more sustainable and adaptive to cope with climate variability's adverse influences. Finally, the study's findings add to the existing literature on climate variability impacts, adaptation, and vulnerability.

The aims of this study are (i) To examine the local's perception, mean surface temperature, and rainfall trend in the district. (ii) To assess the impacts of climate variability on livelihoods. (iii) To assess the most vulnerable groups within the district (iv) To examine the adaptation strategies of the locals to changes in climate.

MATERIALS AND METHODS

Study location and size

The study was conducted in Soroti District, located in Eastern Uganda (Figure 1). It bordered Kumi and Pallisa districts, Lake Kyoga in the South, Kaberamaido in the west, and Katakwi in the Northeast. The district covers a total land area of 2,662.5 km^{2,} of which 406 km^2 is water, and 2,256.5 km^2 is land. The district lies at 1°34'60" N and 33°34'60" E, 1,097 meters above sea level. Soroti District is administratively divided into three (3) rural counties of Serere, Soroti, and Kasilo, and 1 Municipality, Soroti Municipality. In addition, there are 10 Sub-counties, 41 rural parishes, and 511 Local Council 1 units. The Local Councils (LC) make up the political structures, i.e., LC V at the district level and LC 1 at the village level.

Study design

A case study design was used since the emphasis of this study was to undertake an intensive examination of the impacts of climate change and variability on adaptive strategies, livelihoods, and vulnerability within a specific location. The case study design is important in gathering data through observing people's actions and situations and exploring the individuals' preferences, behaviors, and attitudes. Furthermore, in the case of study research, which a survey can not achieve, the exploratory questions, 'what' and' how,' are useful in harnessing detailed and valuable insights and understanding of the topic (Bryman 2008). Therefore, the case study strategy was both quantitative and qualitative.

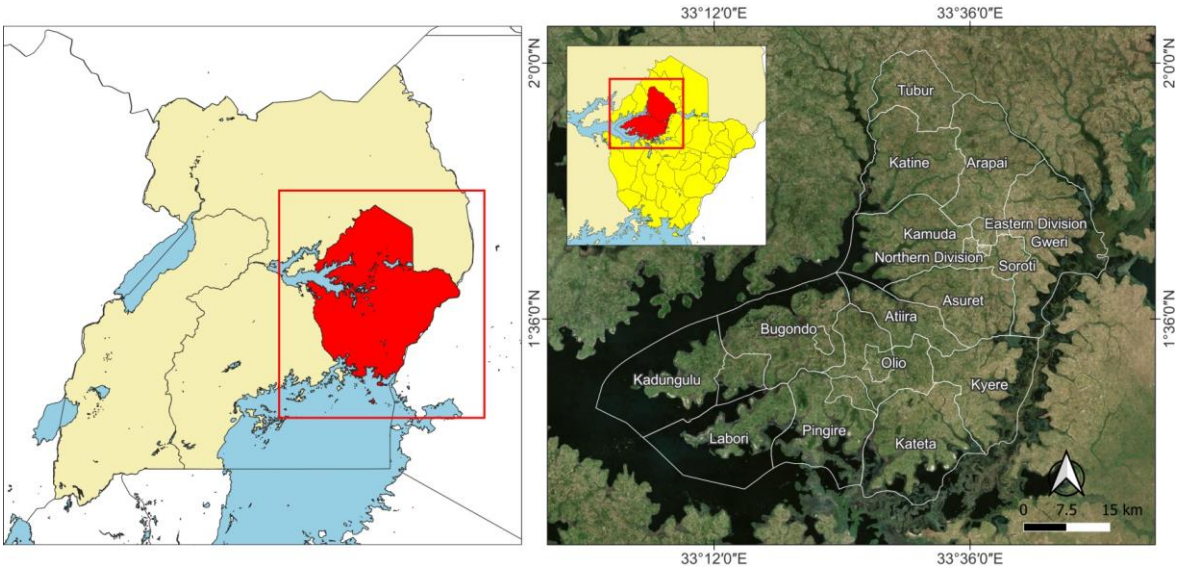


Figure 1. Map of the study area in Soroti District, Uganda

Sample size and sampling procedure

The study adopted the Cochran equation to determine the sample size. However, for large populations, Godden (2004) developed Equation 1 to yield a representative sample for proportions.

The formula is as follows:

$$n_0 = \frac{z^2 p(1-p)}{e^2}$$

Where

n = Sample size

Z = z Value (1.96 for 95% confidence level)

P = Estimated proportion of population (assumed to be 40% or 0.4) e = Margin of error (assumed to be 0.07)

Therefore,

$$n = \frac{1.96 * 1.96 * 0.4(1-0.4)}{0.0049}$$

$n = 180$

The multi-stage random sampling procedure was adopted to select the participating villages and households for the interviews. The 10 Sub -counties within the district were grouped in terms of high, medium, and low agricultural productivity. From each group, one sub-county was randomly selected, making up three Sub-counties. Next, two parishes were randomly selected at the sub-county level, making up 6 parishes. Then, from the 6 parishes, 9 villages were randomly selected. At the village level, systematic random sampling was used to select 20 households in each village, and lists of all households were obtained from local councils (village elders). Overall, 180 households were selected for the interview.

Data sources

Primary data

Household survey. A formal survey was conducted using a standard questionnaire. The questionnaire, which was administered to the household heads, was designed to capture information on family characteristics (family size, age, sex, educational and marital status, major source of income) and other parameters such as local perception of climate change, their coping methods to changing/ unreliable onset of rains; seasonal distribution, rainfall quantity, and intensity. A total of 180 respondents were sampled by interview.

Focused Group Discussion (FGD). Discussions were conducted with local people to get information about the past and present climate conditions, adaptation strategies, and their impacts. A total of three focused group discussions were conducted in Soroti, Katine, and Gweri sub-counties, respectively. Each focused group consisted of five youths, five men, and five women. The timeline and historical profile/ recall methods were used during the discussion to identify extreme climate events and their variability over time, frequency and intensity. In addition, FGD was used to validate and triangulate the responses from the household survey.

Key informants interview. Additional information was gathered from government staff, i.e., District Environment Officer and the District Agricultural Officer. This information was used to cross-check the views of respondents. The interview focused on climate patterns, vulnerable groups, climate variability, change impacts, and possible adaptation measures.

Field observation. Field observations were carried out several times. During the field visit, observations were made on the impacts of climate variability and change on livelihood sources. In addition, observations were carried out in the respondents' homes, farms, and the surrounding environments, and photographs were taken. Finally, the information gathered from the other sources was triangulated by observations.

Secondary data

Climatic data. Rainfall and temperature data from Soroti meteorological station were used to analyze climate change trends and variability. Rainfall data were available from 1961 to 2011, while temperature data were available from 1971 to 2007.

Socio-economic and other data. Socio-economic and other secondary data was obtained from relevant publications like books, journals, internet papers, and research publications. In addition, a literature review was done by concerned agencies such as National Agricultural Research Organization (Uganda) and the IGAD Climate Prediction and Application Center (Kenya) and libraries.

Data analysis

Microsoft-Excel 2007 and the Statistical Package for Social Science (SPSS) 16 Program processed all the quantitative data. Then the results were represented in graphs, charts, and tables. The temperature and rainfall data from Soroti meteorological station trend analysis was done using the Ms-Excel 2007. Results were presented in the form of temperature and rainfall curves and graphs. The third assessment report provided by the IPCC was used to analyze the conceptual framework. The report indicates that vulnerability is a function of the character, rate of climate variation, and magnitude to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2001a,b).

V = f (exposure, sensitivity, and adaptive capacity)

Major climatic hazards of the study area were identified based on exposure of people's livelihood assets like human, physical, biological, social, and financial capital to climate change and variability from the key informants and focused group discussions. Next, they were ranked based on their exposure and sensitivity to five capitals and the households' adaptive capacity to climatic shocks. Next, the vulnerability was assessed as a function of exposure, sensitivity, and adaptive capacity. Finally, Pearson's Chi-square analysis was used in testing the hypotheses.

The equation is specified as follows:

$$x^2 = \sum \frac{(o-e)^2}{e}$$

Where: x^2 = Chi-square statistic, o = Observed values, e = Expected values

RESULTS AND DISCUSSION

Socio-economic profile of sampled households

The socio-economic profile of the community refers to the attributes of sex, levels of education, employment status, income, age, household sizes, and main source of livelihood. These factors play an important role in determining the attitude and vulnerability of the respondents toward adaptation to climate change and variability

Sex and age of the household head

Gender and age are important factors in determining the choice of adaptation strategies and vulnerability since climate change and variability affect men and women of various ages differently, experienced by their distinguished roles and responsibilities at the household and community levels (Aguilar 2009). This study found that 78% of the household heads are male while 22% are female. Regarding age, 33% of the respondents are between 15-35 years, 35% are between 36-55 years, 22% are between 55-64 years, and 10% are between 64 years and above (Figure 2). The results suggest that most household heads in the district are men. That means that men are mostly responsible for making most decisions regarding the welfare of their households and ways of coping and/or adapting to climate change and variability.

A study conducted by Asfaw and Admassie (2004) in Ethiopia indicated that male-headed households have a higher probability of getting information about new farming technologies and undertaking more risky ventures than female-headed households. Also, Tenge and Hella (2004) point out in their study that female-headed households are less likely to adopt soil and water conservation measures since women may have limited access to information, land, and other resources because of traditional social barriers. However, given access to appropriate technology and information, most households in this study likely adopt appropriate coping and adaptation measures, thereby reducing their vulnerability to the impacts of climate variability.

The age of the respondents may also influence the vulnerability and choice of adaptation measures. Croppenstedt et al. (2003) argue that age may affect the farmer's choice of adaptation in two ways. On the one side, it may negatively influence the decision to adopt new technologies simply because older farmers are less likely to be flexible and more risk-averse than younger farmers. On the other side, age may positively influence the decision to adopt because older farmers than younger farmers have more experience in farming and are better able to assess the characteristics of new technology.

The study shows the proportion of the elderly population compared to the younger population within the district is smaller (10%). That means the district's vulnerability in terms of age is lower since, unlike the elderly, the younger population is more likely to cope with the effects of climatic extremes.

Education level of household head

Education plays an important role in an individual's personality development and also has an important role in nation-building, as there is a strong relationship between education and economic development. However, the results show that 13% of the respondents are illiterate, 65% have a primary school education, 15% have secondary education, 3% have higher education (A levels), and only 4% have acquired tertiary education (Figure 3). The probable cause of this low education status is poor economic conditions; hence people tend to abandon education to satisfy their needs. The secondary schools are also very far away from the villages, and students must cover long distances to reach them.

People with formal education, according to Nabikolo et al. (2012), are better able to respond to climatic shocks, thereby reducing their vulnerability. Maddison (2007) also emphasizes that educated and experienced farmers must have more information and knowledge about climate variability and change and adaptation measures necessary to respond to climate challenges. In addition, Norris and Batie (1987) also assert that a higher education level farmer can access information on improved technologies for higher productivity.

The low education levels within the local district could enhance their vulnerability to climate change and variability impacts, limiting their knowledge of high technology adaptation measures and climate variability.

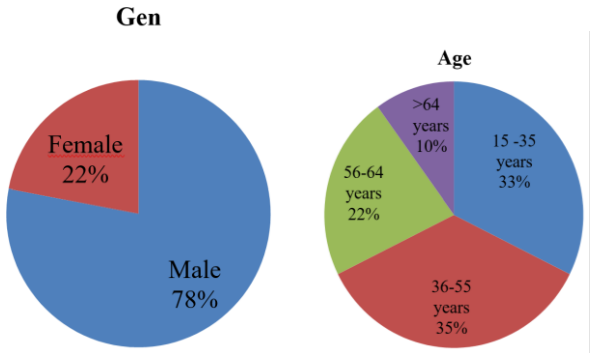


Figure 2. Sex and age of the household head.

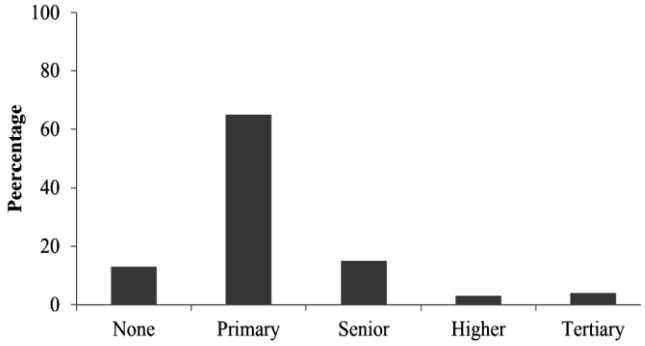


Figure 3. Education level of the household head.

Employment status and income levels

Employment and income are other important factors influencing the decision to adapt to climate change and variability. Table 1 indicates that most respondents (77.4%) are employed (i.e., full-time, part-time, or self-employed), which shows a significant number of unemployed respondents (19.3%). Figure 4 indicates that a majority (33.3%) of the respondents earn below 100,000 UG shillings (3,400 Ksh.). In contrast, the least number (3.3%) earn above 500,000 UG shillings (16,500 Ksh), with a significant number not earning any income (38.3%).

Income earnings

The low employment and income levels are proven to be living in the district. Even those engaged in some form of employment have low-income levels (Figure 4), indicating high vulnerability levels in the entire district. Anley et al. (2007) argue that improving education, income, and employment levels are important in stimulating local participation in various adaptation measures and natural resource management initiatives and reducing vulnerability to climate change. Those with better income are considered less vulnerable to climate variability and change impacts because they can use their resources to cope with climatic extremes.

Household size

Figure 5 indicates that most households have an average of 6-10 members. That is slightly above the national average household size of 5 persons per household (UBOS 2009).

Table 1. Showing the employment status of the household heads

Employment status	Frequency	Percentage
Full-time work	18	10.5
Part-time work	55	30.4
Self-employed	66	36.5
Homemaker	1	0.6
Retired	3	1.7
Student	2	1.1
Unemployed	35	19.3
Total	180	100.0

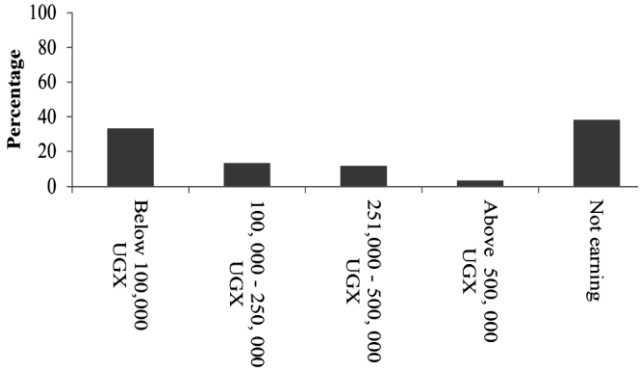


Figure 4. Income levels

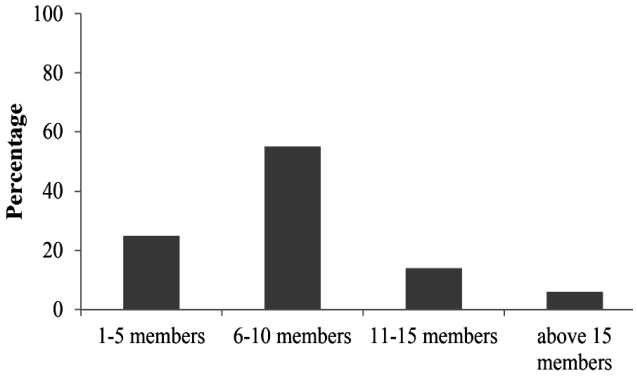


Figure 5. Size of the households

Given the low levels of education (Figure 3) and low-income status (Figure 4), due to consumer pressure imposed by large families, vulnerability to climate change and variability in the district is likely to be heightened. However, Yirga (2007) observes that large families may be able to divert part of the labor force to off-farm activities to earn income to ease the consumption pressure imposed. He also argues within a large family has a higher labor endowment, likely supporting it to accomplish various agricultural tasks. Croppenstedt et al. (2003), on the other hand, assert that households with a larger labor pool, because they have fewer labor shortages at peak times, are more likely to adopt agricultural technology and use it more intensively. Furthermore, given appropriate support, households within the district can utilize their large labor pool, enabling them to cope with climatic extremes in farm and non-farm activities to earn extra income.

Main house construction materials

The houses' construction materials also help in determining vulnerability to climatic extremes. For example, most of the main houses in Soroti (Table 2) have grass-thatched roofs (81.8%) and walls that are made of unbaked bricks (48.6%). The condition of the main house increases the vulnerability levels of the locals to extreme climatic shocks. Since these houses are constructed using unbaked bricks and grass, such as temporary materials, they can be easily swept away by extreme weather events such as floods.

Table 2. Main house construction materials

Construction materials		Frequency	Percentage
Type of walls	Mud & Wattle	63	34.8
	Wood panel	1	0.6
	Unbaked bricks	88	48.6
	Stones	1	0.6
	Baked bricks	27	15.5
	Total	**180**	**100.0**
Type of roof	Grass thatched	148	81.8
	Iron sheet	31	17.7
	Tiled	1	0.6
	Total	**180**	**100.0**

Access to facilities and services

Ease of access to markets, hospitals, credit, and other services could reduce vulnerability significantly. The study indicated that 100% of the respondents interviewed have no access to television, while most respondents (69.1%) have radio access. In addition, 100% of the respondents have no access to electricity, and only 27.6 % have access to credit (Table 3). Table 4 shows that most of the respondents can access certain facilities within a short time, within an hour; for instance, 38.7% can access the nearest market in less than an hour, 46.1% can access the nearest health center in less than an hour, and 59.1% can access the nearest vehicle station in less than an hour.

Access to facilities such as television and radio could increase access to information required for deciding on climate change adaptation. Various studies indicate a strong positive relationship between access to information and the adaptation behavior of farmers in developing countries (Yirga 2007). Furthermore, through extension services, access to information also increases the possibility of adapting to climate change (Nhemachena and Hassan 2007). In addition, ease of access to facilities such as markets, vehicle stations, and hospitals can help reduce vulnerability to climatic shocks.

The main source of livelihood

Most of the respondents (91%) depend on farming as their main source of livelihood (Figure 6). However, most respondents (73.9%) also practice mixed farming. The crops grown and livestock are for subsistence and commercial purposes (Tables 4 and 5).

Table 3. Access to facilities and services

Facility / Service		Frequency	Percent
Access to television	No	180	100.0
Access to	Yes	124	69.1
Radio	No	56	30.9
	Total	**180**	**100.0**
Access to Electricity	No	180	100.0
Access to	Yes	50	27.6
Credit	No	130	72.4
	Total	**180**	**100.0**

Table 4. Ease of access to various facilities

	Time taken	Frequency	Percentage
Time took to reach nearest vehicle station	Less than one hour	107	59.1
	One hour	39	21.5
	More than one hour	34	19.3
	Total	**180**	**100.0**
Time took to reach the nearest health center	Less than one hour	83	46.1
	One hour	36	20.0
	More than one hour	61	33.9
	Total	**180**	**100.0**
Time took to reach the nearest market	Less than one hour	70	38.7
	One hour	42	23.2
	More than one hour	68	38.1
	Total	**180**	**100.0**

Table 5. Type of farming practiced

Description of farming		Frequency	Percent
Type of farming	Crop farming only	41	22.8
	Livestock rearing/herding only	6	3.3
	Mixed farming (Crop & Livestock production)	133	73.9
	Total	180	100.0

Table 6. Type of agriculture practiced

Type of agriculture practiced	Rain-fed	175	97.2
	Irrigated	1	0.6
	Not farming	4	2.2
	Total	180	100.0
Reason for doing farming	Subsistence	36	20
	Commercial	0	0.0
	Both subsistence & commercial	140	77.8
	N/A	4	2.2
	Total	180	100.0

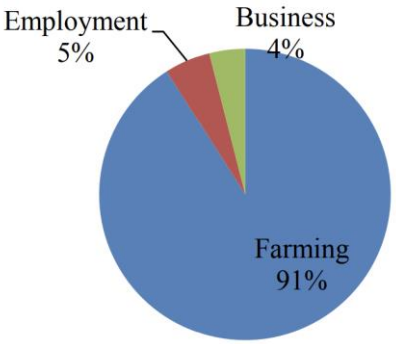


Figure 6. Sources of livelihoods. Source: Field data, 2013

Results from Figure 6 and Table 6 indicate that the main source of livelihood in the Soroti District is rain-fed agriculture. However, rain-fed agriculture is highly vulnerable to climate change and variability (Eriksen 2000; FAO 2008). Therefore, it is highly affected by unseasonal and irregular rainfall patterns, negatively affecting crop farming and livestock. The impacts can include a lack of feed for cattle and crop failure, animal diseases, and lack of water. Therefore, these impacts increase the risk of food insecurity and threaten the people's main source of livelihood. For instance, the extended dry spell in the 2013 March-April-May (MAM) season led to serious crop failure within the district.

Perception and trend of climate change and variability

Respondent's perception of climate variability and change

Local knowledge and perception about climate change are very important in enabling the locals to cope with the negative impacts of climate variability. Table 7 shows that most respondents (97.8%) had mentioned changes in climate and its variables over the past years. For example,

most respondents (72.3%) described that the rainfall onset was late, while the biggest fraction (66.1%) described that rainfall amounts were less. More so, slightly less than half of the respondents reported that seasonal rainfall distribution was heavier in the second season (48.6%), whereas the highest proportion mentioned that cessation was early (64.4%). Most respondents (70.7%) also felt that the temperatures were increasing.

The results show that the respondents are aware of climate change and variability and have noticed changes in weather patterns over the last 5-30 years. The variation in temperature increase and rainfall amounts was found to significantly negatively affect farming, which is the main source of livelihood. The indication that there had been a significant change in climate over the past years resulted from three different focus group discussions. Based on their local knowledge, there was a consensus that rainfall patterns have been erratic between genders over the last three decades.

The variability in rainfall patterns makes it increasingly difficult to plan land preparation and planting times, argued one participant. The dry spells have become more frequent and severe, and the rains start late and end early, sometimes with an extended dry spell between seasons, argued another participant. He further stated that "this unpredictable rainfall pattern in 2013 led to serious crop failure in the first season."

Climate trend analysis

Rainfall analysis

The trend analysis on rainfall shows some significant changes in rainfall patterns. The average annual rainfall pattern over the past 50 years in the Soroti District (1961-2011) shows a decreasing trend in rainfall amounts. The analysis also shows that there has been a significant variation in rainfall within the district in the last 50 years (1961-2011), with a significant decline in the years 1980, 1987, 1993, 2004, and 2011 and a considerable increase in the years 1975, 1978, 1991, 1996, and 2000 (Figure 7).

The respondents' perceptions are aligned with the actual climatic data. Rainfall data shows that the potential crop growing period is shrinking, maybe because the average annual rainfall is decreasing in the Soroti, which is well collaborated by most respondents (66 .1%) reporting that the rainfall amounts are light (Table 7). The variations in the rainfall pattern are very significant for the locals because any changes in rainfall will hamper crop production because they are directly dependent upon rain-fed agricultural practices. Excessive rainfall could cause flooding and soil erosion, while a decline in rainfall could lead to crop failure.

Annual average rainfall in decades

Figure 8 shows an analysis of the annual rainfall averages for five decades, showing that the highest rainfall amounts occurred in the 1961-1970 and 1981-1990 decades. The lowest rainfall amounts were experienced in the 1971-1980 and 2001-2010 decades. There is also a notable rainfall reduction in the last decade (2001-2010).

Table 7. Perception and knowledge of climate change and variability

		Frequency	Percent
Respondents who have observed changes in weather patterns over the last 5-30 years	Yes	177	97.8
	No	3	2.2
	Total	180	100.0
Changes observed (rainfall)			
Rainfall onset	Early	18	10.2
	Normal	3	1.7
	Late	128	72.3
	Variable	28	15.8
	Total	177	100.0
Rainfall amounts	Light	117	66.1
	Normal	6	3.4
	High	9	5.1
	Variable	45	25.4
	Total	177	100.0
Rainfall seasonal distributions	Normal	7	4.0
	Heavier in the first season	32	18.1
	Heavier in the second season	86	48.6
	Drought interspersed within seasons	23	13.0
	Variable	29	16.4
	Total	177	100.0
Cessation (end of rainy season)	Early	113	64.4
	Normal	9	5.2
	Late	55	30.5
	Total	177	100.0
Temperature	Lower	15	8.6
	Moderate	24	13.2
	Higher	124	70.7
	Variable	14	7.5

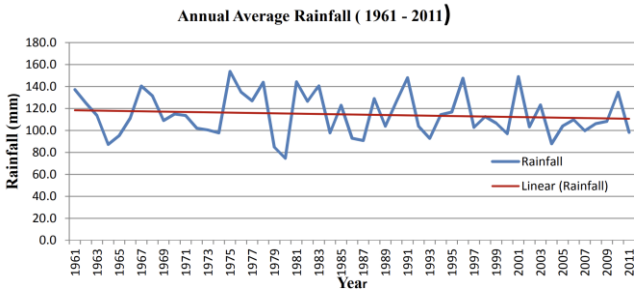


Figure 7. Annual average rainfall from Soroti meteorological station (1961 -2011). Source: Soroti Meteorological Station 2013

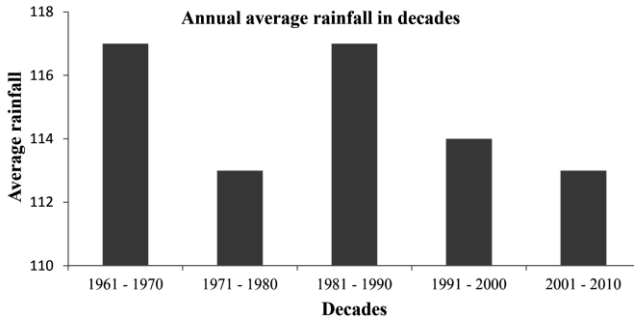


Figure 8. Annual average rainfall in decades. Source: Soroti Meteorological Station (2013)

Temperature analysis

The temperature data for Soroti obtained from meteorological data for 1971-2007 were analyzed, resulting in Figures 9 and 10 indicating some visible temperature changes for 36 years (1971-2007). Over the years, there has been a significant increase in both the maximum and minimum temperatures. This increase in temperature leads to a significant decline in available water resources and could hamper plant growth.

Average maximum temperature in decades

Figure 11 shows the increasing trend of temperatures in decades. For example, the average decade temperature calculated for 1971-1980, 1981-1990, and 1991 -2000 provide 29.8º, 29.9º, and 30.6º, respectively, with the highest increase in the last decade.

Figures 9, 10, and 11 show the temperature variability of the area. The general trend in the aggregate mean annual temperatures from 1971 to 2007 gradually increased. For example, from a low of 29.8 ºC in the 1971-1980 decade, maximum temperatures increased to 30.6ºC in the 1991-2000 decade (Figure 11), which shows an increase of 0.8ºC between the 1981 - 1990 and 1990 -2000 decades. That increase could have an enormous effect on agriculture due to evaporation and evapotranspiration rates, thereby reducing soil moisture.

A study by Ouedraogo et al. (2006) conducted in Burkina Faso found that a 1°C increase will reduce farm revenue by 19.9 US$/ha, while if precipitation increases by 1 mm/month, net revenue will increase by 2.7 US$/h using a standard Ricardian model. Those findings show that agriculture is very sensitive to precipitation in Burkina Faso. In Ethiopia, the results are not different. A study by Deressa (2006) in Ethiopia reveals that net farm revenue would fall in summer and winter if temperature increases, whereas increasing precipitation during spring will increase net farm revenue. In Ethiopia, the results are not different from Burkina Faso.

Type of climatic shock that is the main concern

Figure 12 shows that drought was stated as the most frequent climatic shock of main concern, followed by floods in the Soroti District.

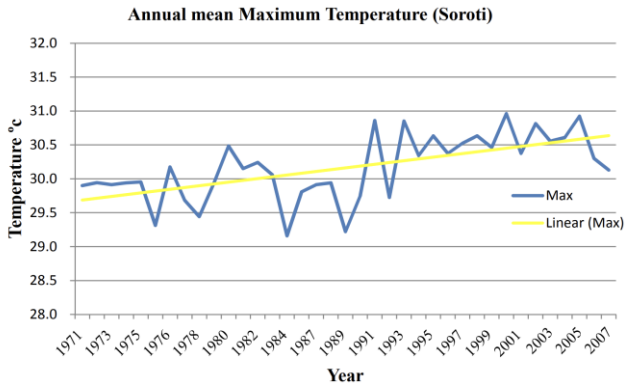


Figure 9. Annual mean maximum temperatures (1971-2007). Source: Soroti Meteorological Station (2013)

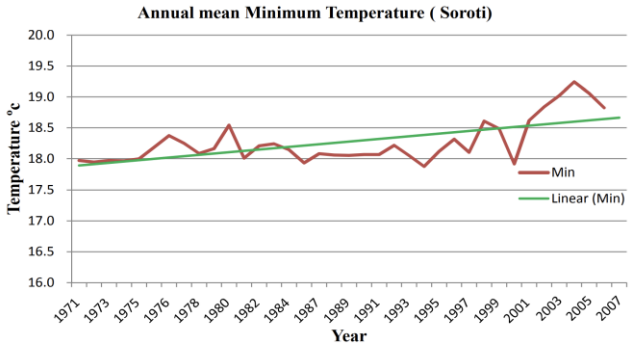


Figure 10. Annual mean minimum temperature (1971-2007). Source: Soroti Meteorological Station (2013)

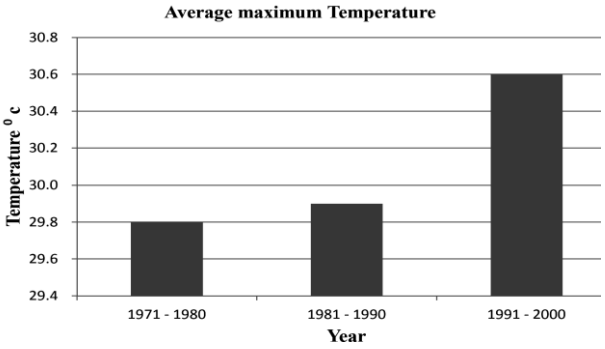


Figure 11. Average maximum temperatures in decades. Source: Soroti Meteorological Station (2013)

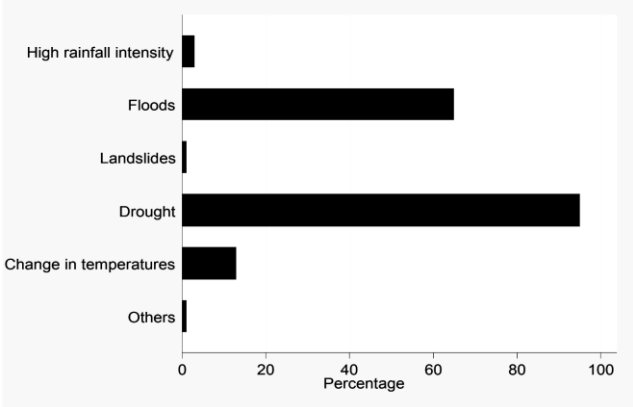


Figure 12. Shows the type of climatic shock that is of main concern to the residents

Hypothesis 1: There is no significant variation in climatic extremes such as drought and floods across different villages in the Soroti District

Drought, land degradation, ecosystem degradation, and flood hotspots within Soroti District were identified by testing the relationship between the village of residence and the type of climatic shock experienced at a 95% confidence level, as shown in Table 8: (i) A significant relationship was established between the type of climatic shock experienced and the village name of residence ($p < 0.05$). (ii) High rainfall intensity was witnessed in Aputon compared to other villages (10.5%). On the other hand, floods were witnessed most in Asinge village compared to the others (66.7%). (iii) Drought was common in Omirio compared to other villages (69%). (iv) Temperature

changes were experienced most in Aputon compared with other villages (26.3%). On the other hand, landslides had not been experienced by most of the locals in the district.

Impact of climate change on livelihoods

The evidence gathered during the respondent's interview suggests that climate change and variability have frequently been imposing various challenges on their livelihoods and consequently affecting the society's socio-economic activity of the local people. For example, Table 7 shows that the main impact on crop farming in Soroti District of climate change and variability is crop damage (56.1%). In comparison, the main impact on livestock farming is the lack of animal feed (28.9%).

Regarding fishing, the main impact of climate change and variability was low fish catches reported by the biggest fraction of households (41.1%). Most respondents stated the main impact of climate change on water resources was decreased water availability (73.9%). The biggest fraction of respondents (38.9%) reported the main impact of climate change on land resources was a decline in soil fertility (Tables 8 and 9).

Agriculture in the Soroti District is purely rain-fed and is the main livelihood source for 91% of the respondents (Figure 6). The irregular and unseasonal rainfall patterns have negatively affected crop and livestock farming, threatening people's food security and well-being. The main impacts in the Soroti District of climate variability and change have been crop damage and, in some instances, total crop failure due to delays in the onset of rains and extended dry spells. As the focus group discussions noted, the extended dry spells in the 2013 March-April-May (MAM) season significantly negatively impacted the harvest and the general household food security. It led to subsequent poor harvests and serious crop damage.

The study found that concerning livestock production, drought and delay in the onset of rain led to poor grass regeneration and forage deficit, heat stress on livestock, and water shortage, consequently increasing livestock mortality. The information gathered from the District Agricultural officer indicated that the animals were more susceptible to diseases, such as sheep and goat pox, *coccidiosis*, anthrax, and *Salmonelliosis.* The impact of climate change on the distribution of several infectious disease vectors and the seasonal distribution of some allergenic pollen species was highlighted by the IPCC's fourth assessment report. According to this report, diseases previously limited to low latitudes have spread to higher latitudes. Insect-borne diseases such as *anaplasmosis* and *trypanosomosis* are now found in many parts of the world where their vectors have never been found in the past. In association with land use change, the climate has been associated with global increases in mortality and morbidity from emergent parasitic diseases (IPCC 2007).

Table 9. Impacts of climate change and variability on agriculture

Livelihood source	Impact	Frequency	Percent
Crop farming	Crop failure	72	40
	Crop damage	101	56.1
	Pest infestation	4	2.2
	Others	1	0.6
	N/A	2	1.1
	Total	**180**	**100.0**
Livestock farming	Lack of feeds	52	28.9
	Water shortage	34	18.9
	Low milk production	4	2.2
	Small grazing areas	24	13.3
	Disease prevalence	22	12.2
	Death of livestock	10	5.6
	Others (n/a)	34	18.9
	Total	**180**	**100.0**

Table 8. Percentage distribution of major climatic shock by the village of residence

Village name		Type of climatic shock that is your main concern						Total
		High rainfall intensity	Floods	Landslide	Drought	Change in temperatures	Others	
Aputon	Count	2	3	0	9	5	0	19
	% Within village	10.5	15.8	0.0	47.4	26.3	0.0	100.0
Ojwiny	Count	0	4	0	4	1	1	10
	% Within village	0.0	40.0	0.0	40.0	10.0	10.0	100.0
Agora	Count	0	12	0	18	1	0	31
	% Within village	0.0	38.7	0.0	58.1	3.2	0.0	100.0
Amen A	Count	1	9	0	15	5	0	30
	% Within village	3.3	30.0	0.0	50.0	16.7	0.0	100.0
Omirio	Count	0	8	1	20	0	0	29
	% Within village	0.0	27.6	3.4	69.0	0.0	0.0	100.0
Otidonga	Count	0	6	0	8	0	0	14
	% Within village	0.0	42.9	0.0	57.1	0.0	0.0	100.0
Asinge	Count	0	10	0	5	0	0	15
	% Within village	0.0	66.7	0.0	33.3	0.0	0.0	100.0
Olelai	Count	0	6	0	4	0	0	10
	% Within village	0.0	60.0	0.0	40.0	0.0	0.0	100.0
Gweri	Count	0	7	0	12	1	0	20
	% Within village	0.0	35.0	0.0	60.0	5.0	0.0	100.0
Total	Count	3	65	1	95	13	1	178
	% Within village	1.7	36.5	0.6	53.4	7.3	0.6	100.0

Note: Test of hypothesis/Significance: Chi-square=64.673. Degrees of freedom=40 p-value=0.008

Heavy rainfall was found to negatively and positively impact livestock production. The negative ones include livestock deaths from bloating and over-eating weak animals that survived the drought. In contrast, the positive impacts include increased water availability and enhanced grass regeneration, as noted in the focused group discussions.

Natural ecosystems and biodiversities are also affected by the changing climate. For example, respondents from the focused group discussion cited that they have experienced the loss of some native plants and species within the surrounding forests, grassland, and wetlands. In addition, 41.1% of the respondents from the household survey also indicated that they are experiencing low fish catches due to reduced fish quantities.

Even though there are sufficient water sources, as observed from the numerous wells and boreholes within the district, the local people said they are facing more dry spell periods resulting in decreased water in these sources, which may affect agriculture and food security. The other impact of climate variability and change include soil erosion and the decline in soil fertility from heavy rainfall, especially in flood-prone Gweri Sub-county.

Vulnerability

Vulnerable groups

The highest proportion of the respondents (39%) felt that women are most vulnerable, next to the poor (31%) and the less educated (14%) (Figure 13).

The poor

The District Environment Officer (DEO) pointed out that because of their dependence on a natural resource such as land as their source of livelihood, the poor are more vulnerable to climatic shocks; hence their sources of livelihood are negatively impacted when there is drought or floods, making them more vulnerable. In addition, the poor depend on daily wage labor, have fewer reserves to absorb climatic shocks, and have lower incomes. Respondents from the focused group added that due to the general perception that they cannot afford to pay it back, the poor do not have access to loans and credit.

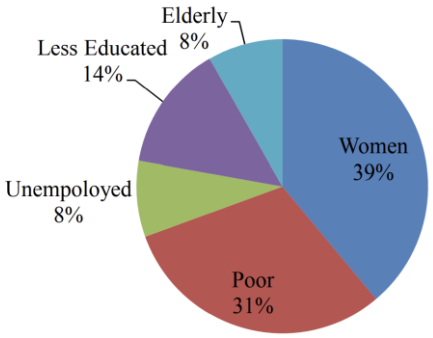


Figure 13. Vulnerable groups. Source: Field Data (2013)

Figure 4 indicates that the majority of those working earn below 100 thousand Ugandan shillings per month, which are supposed to be low-income levels, thus increasing their vulnerability to climatic extremes. Furthermore, the condition of the study areas shows that they are mostly made of unbaked bricks and wood, which are traditional houses. That also displays the vulnerability of the whole community during natural disasters, especially in Gweri Sub-county, which is considered flood-prone. Cross-referencing employment status, education levels, and house construction structure show the district's poverty level. A study conducted in Bangladesh by Brouwer et al. (2007) shows that households with less access to productive resources and lower income are more vulnerable to climatic risk exposure. They also show that with the presence of income and asset disparity and under the climatic shock, individual households become more vulnerable at the community or collective level since the collective level is least capable of facing a common shock like a flood.

Women

Results from the household survey, the key informant interviews, and focused group discussions indicate that women are more vulnerable to climate change and variability than men. Women's vulnerability was explained by their confinement at home caring for children and family members, poor nutritional status, a lack of access to the property, and lack of empowerment. According to the district, Environment officer, "Women's Women's closeness to family members and confinement at home and closeness to family members makes them most suffering because men can move to look for an alternative source of livelihood to nearby towns."

Aguilar (2009) argues that women tend to have more limited access to the assets (financial, human, social, physical, and natural capital) that would enhance their capacity to adapt to climate change, such as land, decision-making bodies, agricultural inputs, technology, credit, and extension and training services. Thus any climate adaptation strategy should include ways to reduce climate-related risks and actions to build up women's assets, such as improving their access to skills, knowledge, and education and strengthening their ability to prepare for and manage risks.

Less educated

The education status of the household heads has been explored through the survey (Figure 3). The study shows that many interviewed people have completed primary education, but many respondents have been presented as illiterate. Higher, secondary, and Tertiary education has been achieved by a very small percentage of the respondents. The overall education status of the household heads shows adult literacy level is lower in the community as a whole. Yet, adults' higher education levels increase the possibilities of creating new ideas and open-mindedness. Adults in this community are less likely to adopt alternative livelihoods if it becomes necessary due to climate variability and change.

Vulnerability by the source of livelihood

Results from Figure 6 indicate that most respondents (91%) indicated that farming is their main source of livelihood. Furthermore, most respondents (97.2%) also indicated that they practiced rain-fed agriculture (Table 6). That means they directly depend on rainfall in their farming practices; even the district's agriculture sector is dominated by small-scale farmers, who depend on rain for crop production. However, most studies agree that rain-fed agriculture is highly vulnerable to climate change and variability (Eriksen 2000; FAO 2008). Therefore, any climate change mostly manifested as an increase in low rainfall amounts, frequency, and severity of extreme weather events such as floods and drought can significantly reduce household food security and agricultural production.

Hypothesis 2: Vulnerability to climatic extremes varies significantly with the education levels of the household heads

The relationship could not be established significantly between the type of climate-related risk experienced and the education level of the household head ($p > 0.05$). That implies that vulnerability does not vary with the education level of household heads.

Coping and adaptation strategies

The results show that the highest proportion (33.3%) of households applied wage labor as a major coping mechanism to the climatic risk once they had experienced drought. The biggest fraction of households (23.9%) also applied grain storage as a major coping mechanism to the climate risk once they had experienced floods. The largest proportion of households (21.7%) applied wage labor as a major coping mechanism to the climatic risk once they had experienced a poor harvest. Finally, the biggest fraction of households (19.4%) also applied grain storage as a major coping mechanism to the climatic risk once they had experienced food shortages (Tables 12 and 13).

When faced with the above unpredictable climate-related risks, the Soroti District residents adopt different coping mechanisms. Much of this response is reactive because it is triggered by current or past events such as drought and floods. Still, it is also anticipatory as it is based on some assessment of conditions in the future, for example, rainfall occurrence. Therefore, some coping strategies are adopted before the occurrence of the climatic risk, while others are activated as the risks develop.

This study shows that the most common coping mechanisms to reduce vulnerability to climatic shocks employed by the locals are wage labor (farm or non-farm activities that the locals engage in to earn income) and grain storage (Tables 10 and 11). However, these coping strategies are not sustainable because employment opportunities are not always available to the locals. When there is a poor harvest, the people lack enough grain to store for future use.

Adaptation technologies

Results show that the main adaptation strategies to climate shocks are shifting planting dates (95.6%), crop diversification (86.7%), and diversifying from farming to non-farming activities (54.5%). Moreover, it was also cited that a smaller percentage of households significantly use irrigation (3.3%) (Table 14).

Table 14 shows that to deal with various climatic risks, most households in this study preferred multiple adaptation measures. For instance, most households employed shifting planting dates, crop diversification, and diversifying from farming to non-farming activities to deal with climatic extremes.

For the local people, to an extent, crop diversification guarantees good harvests; however, there are many years in which farmers report a total crop failure. Therefore, policies on adaptation that target such farmers to ensure that feasible farmer adaptations are promoted and supported should be worked out consultatively with farmers. Furthermore, the cultivation of both short and long-cycle crop varieties enables households to take advantage of the maturing times of crops to strengthen their resilience to increase chances of having good harvests during the drier and wetter seasons to impacts associated with unpredictable and variable rainfalls and drier conditions. For instance, in Gweri Sub-county, the locals have ventured into rice farming in nearby wetlands.

Consistent with a study conducted in Tanzania, diversification has been identified as a potential farm-level adaptation to climatic variability. Paavola (2004) found out that farmers switch between crops, alter the mix of crops, and change planting dates in light of the evidence they obtain of the growing season. Another study by Ssewanyana and Kasirye (2010) found that farmers in Uganda, as a form of insurance against rainfall variability and pests attack, use mixed cropping and diversification of crops.

Table 10. Impacts of climate change on natural resources

Natural resource	Impact	Frequency	Percentage
Fishing	Low fish catches	74	41.1
	High fish catches	6	3.3
	Low fish weight	23	12.8
	Decreased fish varieties	13	7.2
	Increased fish variety	1	0.6
	Low volumes of water	15	8.3
	High volumes of water	3	1.7
	Others(N/A)	45	25
	Total	**180**	**100.0**
Water resources	Increased water availability	22	12.2
	Decreased water availability	133	73.9
	Decreased water quality	24	13.3
	Others	1	0.6
	Total	**180**	**100.0**
Land resources	Decline in soil fertility	70	38.9
	Soil erosion	22	12.2
	Land degradation	20	11.1
	Loss of vegetable cover	62	34.4
	Loss of indigenous plants	2	1.1
	Others	4	2.2
	Total	**180**	**100.0**

Table 11. Distribution of climate-related risks by the education level of household head

Climate-related risk experienced		Education level of household head					
		None	Primary	Senior	Higher	Tertiary	Total
Droughts	Count	22	97	25	2	7	153
	% within education level	88.0	85.8	83.3	100.0	87.5	85.9
Floods	Count	17	66	13	1	3	100
	% within education level	68.0	58.4	43.3	50.0	37.5	56.2
Landslides	Count	0	0	0	0	0	0
	% within education level	0.0	0.0	0.0	0.0	0.0	0.0
Hailstorms	Count	1	9	5	0	0	15
	% within education level	4.0	7.9	16.7	0.0	0.0	8.4
Disease & pest epidemics	Count	4	21	5	1	2	33
	% within education level	16.0	18.6	16.7	50.0	25.0	18.5
Lightning strikes	Count	0	0	0	0	0	0
	% within education level	0.0	0.0	0.0	0.0	0.0	0.0
Bush fire	Count	0	0	1	0	0	1
	% within education level	0.0	0.0	3.3	0.0	0.0	0.56
Decreasing water resources	Count	4	5	0	1	0	10
	% within education level	16.0	4.4	0.0	50.0	0.0	5.6
Invasive weeds	Count	0	3	1	0	0	4
	% within education level	0.0	2.7	3.3	0.0	0.0	2.2
Extinction of some indigenous species	Count	0	2	0	0	0	2
	% within education level	0.0	1.8	0.0	0.0	0.0	1.1
Lack of pasture	Count	3	10	5	0	2	20
	% within education level	12.0	8.85	16.7	0.0	25.0	11.2
Poor harvest	Count	15	79	20	1	3	118
	% within education level	60.0	69.9	66.7	50.0	37.5	66.3
Food shortage	Count	21	74	19	2	5	121
	% within education level	84.0	65.5	63.3	100.0	62.5	67.9
Increasing water volumes	Count	1	2	2	0	0	5
	% within education level	4.0	1.77	6.7	0.0	0.0	2.8
Total	Count	88	368	96	8	22	582
	% within education level	352.0	325.7	320.0	400.0	275.0	326.9

Note: Test of hypothesis/Significance: Chi-square=206.714. Degrees of freedom=204 p-value=0.396

Table 12. Coping mechanisms applied for the major climatic risks

Climate-related risk	Coping mechanism	Freq.	%
Drought	Sell household assets	21	11.7
	Reduced socialization for saving	2	1.1
	Wage labor	60	33.3
	Making local drink	10	5.6
	Petty trading	35	19.5
	Grain storage	40	22.2
	Credit from merchants or money lenders	2	1.1
	Buy food on credit	7	3.9
	Consumption of wild fruits/ game meat	3	1.7
	Total	180	100.0
Floods	Sell household assets	20	11.1
	Government assistance	2	1.1
	Wage labor	33	18.3
	Petty trading	34	18.9
	Migration in search of employment	2	1.1
	Grain storage	43	23.9
	Buy food on credit	15	8.3
	Conservation Agriculture	31	17.2
	Total	180	100.0

Table 13. Coping mechanisms during poor harvest and food shortage

	Coping mechanism	Freq.	%
Poor harvest	Sell household assets	10	5.6
	Wage labor	39	21.7
	Making local drink	12	6.7
	Petty trading	21	11.7
	Reduction of consumption level	30	16.7
	Grain storage	30	16.7
	Buy food on credit	31	17.2
	Borrowing food	4	2.2
	Others (food aid)	3	1.7
	Total	180	100.0
Food shortage	Sell household assets	10	5.6
	Wage labor	30	16.7
	Petty trading	23	12.8
	Giving community service (food for work)	5	2.8
	Reduction of consumption level	34	18.9
	Migration in search of employment	13	7.2
	Grain storage	35	19.4
	Borrowing food	24	13.3
	Consumption of wild fruits/game	3	1.7
	Others (food aid)	3	1.7
	Total	180	100.0
	Buy food on credit	31	17.2
	Borrowing food	4	2.2
	Others (food aid)	3	1.7
	Total	180	100.0

Table 14. Adaptation technologies used to deal with climatic shocks

Adaptation strategies to climatic extremes	Yes		No	
	Freq.	%	Freq.	%
Diversify crops	156	86.7	24	13.3
Shift planting dates	172	95.6	8	4.4
Irrigation	6	3.3	174	96.7
Change from crop to livestock farming	2	1.1	178	98.1
Migrate to an urban area	40	22.2	140	77.8
Change the quantity of land under cultivation	21	11.7	159	88.3
Implement soil conservation techniques	57	31.7	123	68.3
Diversify of farming to non-farming	98	54.4	82	45.6

The risk of complete harvest failure due to a climatic event, such as intense rainfall, drought, or high-temperature spells, is reduced by having different crops in the same field or various plots with differing crops since not all crops and fields are affected by the same way by such climate events (Ssewanyana and Kasirye 2010). However, limitations associated with cultivating crops all year round are low yields due to limited time, labor, and capital. Although the migration of family members is very rare in the district, to meet household expenditure in times of food shortage, seasonal migration takes place in search of employment.

Major challenges that hinder effective adaptation

Table 15 shows, as identified in this study that the key issues that hinder effective adaptation include lack of money (33.3%), poverty (27.2%), lack of information (19.1%), and lack of technology (13.4%).

The main constraints that hinder adaptation in Soroti District are a lack of financial resources and poverty. The study found that despite numerous adaptation options that locals were willing to apply and aware of, a lack of sufficient financial resources to purchase the necessary inputs, invest in, and other associated equipment (e.g., seeds, feeds) were significant constraints to adaptation.

It is also apparent that if household members need to change their present occupation because of climate change-related risks, they possibly face great challenges due to poverty and lack of capital, limiting their ability to diversify from farm to non–farm practices. Paavola (2004) indicates that poor households often face constraints and difficulties in agricultural production related to varying climates compared to other households.

Table 15. Major constraints that hinder the ability to adapt

Constraints	Freq.	Percent
Lack of money	60	33.3
Lack of Information	35	19.1
Poverty	49	27.2
Lack of credit	3	1.9
Lack of technology (agricultural inputs)	24	13.4
Lack of Extension service	7	3.9
lack of market access or poor transport link	2	1.2
Total	**180**	**100%**

The other major constraints included a lack of technology and information. Access to technology and extension services can significantly increase the probability of adopting adaptation options. However, the respondents claim they have little access to extension services in the study area. Sometimes, the services and information obtained from the concerned institutions are inappropriate or useless.

REFERENCES

Adger WN. 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Climatic Change 47 (4): 325-352. DOI: 10.1023/A:1005627828199.

Aguilar L. 2009. Women and climate change; Vulnerabilities and adaptive capacities. In: Starke L (eds). State of The World: Into A Warming World. A Worldwatch Institute Report On Progress Towards A Sustainable Society. W.W. Norton & Company, New York.

Anley Y, Bogale A, Haile-Gabrile A. 2007. Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo District, western Ethiopia. Land Degrad Dev 18: 289-302. DOI: 10.1002/ldr.775.

Asfaw A, Admassie A. 2004. The role of education on the adoption of chemical fertilizer under different socio-economic environments in Ethiopia. Agric Econ 30 (3): 215-228. DOI: 10.1111/j.1574-0862.2004.tb00190.x.

Bakari MS, Abdallah JM, Hella JP. 2018. Adaptation strategies of small-scale agriculture production to climate change impacts in Micheweni, Tanzania. Trop Drylands 3: 60-75. DOI: 10.13057/tropdrylands/t030205.

Boon E, Ahenkan A. 2012. Assessing climate change impacts onecosystem services and livelihoods in Ghana: Case study of communities around Sui Forest Reserve. J Ecosyst Ecogr S3: 001. DOI: 10.4172/2157-7625.S3-001.

Brouwer R, Akter S, Brander L, Haque E. 2007. Socio-economic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh. Risk Anal 27: 313-326. DOI: 10.1111/j.1539-6924.2007.00884.x.

Bryman A. 2008. Social Research Methods. Oxford, New York.

Croppenstedt A, Demeke M, Meschi MM. 2003. Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. Rev Dev Econ 7 (1): 58-70. DOI: 10.1111/1467-9361.00175.

Deressa TT. 2006. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. CEEPA Discussion Paper No. 25, Centre for Environmental Economics and Policy in Africa - CEEPA, University of Pretoria, South Africa. DOI: 10.1596/1813-9450-4342.

Dube T, Phiri K. 2013. Rural livelihoods under stress: The impact of climate change on livelihoods in South Western Zimbabwe. Am Intl J Contemp Res 3 (5): 11-25.

Ekere W. 2012. The Impact of Climate Change and Variability on Agricultural Production: Adaptation Strategies in Teso Sub-Region of Eastern Uganda. RUFORUM, Uganda.

Eriksen S. 2000. Responding to Global Change: Vulnerability and Management of Agro-Ecosystems in Kenya and Tanzania. [Thesis]. Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, UK.

FAO. 2008. Climate Change and Food Security: A Framework Document. Rome.

ICRC. 2010. International Committee of the Red Cross. Africa ICRC Annual Report International Food Policy Research Institute (2010). Discussion paper 01042.

IPCC. 2001a. Climate change 2001: Impacts, Adaptation and Vulnerability. Contribution of working group I: The scientific basis to the Third Assessment Report of the Intergovernmental Panel on Climate change, Cambridge University Press, Cambridge, UK, and New York.

IPCC. 2001b. Climate change 2001: Impacts, Adaptation and Vulnerability. Contribution of working group II: Impacts, Adaptation and Vulnerability to the Third Assessment Report of the

Intergovernmental Panel on Climate change, Cambridge University Press, Cambridge, UK, and New York.

IPCC. 2007. Climate Change Impacts, Adaptation and Vulnerability. The Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report.

Kong'ani LNS, Mutune JM, Thenya T. 2018. Analysis of climate change knowledge and its implications on livelihood options around Naituyupaki Location, Maasai Mau Forest, Narok County, Kenya. Asian J For 2: 62-66. DOI: 10.13057/asianjfor/r020204.

Kuria EK, Machuka J, Runo S. 2019. Maize bioengineering with c-repeat binding factor 1 (CBF1) as a technique for drought tolerance. Trop Drylands 3: 1-10. DOI: 10.13057/tropdrylands/t030101.

Loo YY, Billa L, Singh A. 2015. Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia. Geosci Front 6 (6): 817-823. DOI: 10.1016/j.gsf.2014.02.009.

Maddison D. 2007. The Perception and Adaptation to Climate Change in Africa. World Bank Policy Research Working Paper 4308, Sustainable Rural and Urban Development Team. DOI: 10.1596/1813-9450-4308.

Nabikolo D, Bashasha B, Mangeni MN, Majaliwa JGM. 2012. Determinants of climate change adaptation among male and female headed farm households in eastern Uganda. Afr Crop Sci J 20 (2): 203-212.

Nanduddu S. 2007. Lived Experiences: Adaptation to Climate Change in Gogongo Sub County, Palisa District, Uganda.

Nhemachena C, Hassan R. 2007. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. RePEc, Africa.

Norris E, Batie S. 1987. Virginia farmers' soil conservation decisions: an application of Tobit analysis. Southern J Agric Econ 19 (1): 89-97. DOI: 10.1017/S0081305200017404.

Onyekuru AN, Marchant R. 2014. Climate change impact and adaptation pathways for forest-dependent livelihood systems in Nigeria. Afr J Agric Res 9 (24): 1819-1832.

Orindi VA, Eriksen S. 2005. Mainstreaming adaptation to climate change in the development process in Uganda. Africa Portal, Africa.

Ouedraogo M, Some L, Dembele Y. 2006. Economic impact assessment of climate change on agriculture in Burkina Faso: a Ricardian approach ', CEEPA Discussion Paper # 24, Centre for Environmental Economics and Policy in Africa -CEEPA, University of Pretoria, SA.

Paavola J. 2004. Livelihoods, Vulnerability and Adaptation to Climate Change in the Morogoro Region, Tanzania. CSERGE Working Paper EDM, No. 04-12.

Ssewanyana S, Kasirye I. 2010. Food Insecurity in Uganda: A Dilemma to Achieving the Hunger Millennium Development Goal. Economic Policy Research Centre (EPRC); Research Series 70. Uganda.

Suryavanshi P, Babu S, Baghel JK, Suryavanshi G. 2012. Impact of climate change on agriculture and their mitigation strategies for food security in agriculture: A review. ISCAJ Biol Sci 1 (3): 72-77. DOI: 10.1186/2048-7010-1-3.

Tambo JA, Abdoulaye T. 2013. Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna. Reg Env Chang 13 (2): 375-388. DOI: 10.1007/s10113-012-0351-0.

Tenge De Graaff J, Hella JP. 2004. Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania. Land Degrad Dev 15 (2): 99-114. DOI: 10.1002/ldr.606.

Twinomugisha B. 2005. A Content Analysis Reports on Climate Change Impacts, Vulnerability and Adaptation in Uganda. DENIVA, Uganda.

Uganda Bureau of Statistics (UBOS). 2009. Uganda Bureau of Statistics, 2009. Statistical Abstracts. Kampala, Uganda.

Uganda Bureau of Statistics (UBOS). 2011. Uganda Bureau of Statistics, 2009. Statistical Abstracts. Kampala, Uganda.

UNEP. 2009. Enhancing the contribution of Weather, Climate and Climate Change to Growth, Employment and Prosperity. UN Environment Programme.

Wambui MB, Opere A, Githaiga MJ, Karanja FK. 2018. Assessing the impacts of climate variability and climate change on biodiversity in Lake Nakuru, Kenya. Bonorowo Wetlands 8: 13-24. DOI: 10.13057/bonorowo/w080102.

Wasige JE. 2009. Assessment of the Impact of Climate Change and Climate Variability on Crop Production in Uganda. Makerere University, Kampala, Uganda.

Yirga CT. 2007. The Dynamics of Soil Degradation and Incentives for Optimal Management in Central Highlands of Ethiopia. [Thesis]. Department of Agricultural Economics, Extension, and Rural Development. University of Pretoria, South Africa.

INTL J TROP DRYLANDS
Volume 6, Number 2, December 2022 E-ISSN: 2580-2828
Pages: 77-89 DOI: 10.13057/tropdrylands/t060204

Hunter-gatherers' coping strategies on climate change and prospect in Iramba and Mbulu Districts, Tanzania

SELEMAN SHADRACK, J. K. MWALILINO♥
Department of Physical Sciences, Sokoine University of Agriculture. Morogoro, Tanzania. Tel.: +255-23-2640021, ♥email: mwalilino@suanet.ac.tz

Manuscript received: 29 July 2022. Revision accepted: 22 October 2022.

Abstract. *Shadrack S, Mwalilino JK. 2022. Hunter-gatherers' coping strategies on climate change and prospect in Iramba and Mbulu Districts, Tanzania. Intl J Trop Drylands 6: 77-89.* The study intended to establish community perceptions of climate change, assess the extent of food availability and stability, and identify Hadzabe's food insecurity coping strategies toward climate change. The study was arranged in five villages in Iramba and Mbulu Districts, Tanzania: Yaedachini, Mongo wa Mono, Kipamba, Munguli, and Domanga. Furthermore, to collect data, the cross-sectional technique was used. Next, purposive and simple random sampling was used to obtain 100 respondents. Next, data were analyzed using computer programs and content analysis methods. Finally, descriptive statistics such as frequencies and percentages were computed. This study revealed that people had experienced climate change that led to chronic food insecurity. However, the Hadzabe have developed different coping strategies to mitigate this situation. The most used coping strategies included: relying on food from the government and NGOs, migrating to the area with food, borrowing food and selling labor, eating foods that have not been used before, and engaging in petty business. In Hadzabe, the dependence on wild food and lack of food storage facilities and habits were identified as the main contributing factors to food insecurity. The study concluded that there is a need to improve the coping capacity of the Hadzabe to strengthen their coping strategies and to recognize the importance of forest resources in supporting the Hadzabes' livelihoods to improve food availability and stability. This study recommended long-term development measures such as training on crops, animal husbandry, and modern beekeeping.

Keywords: Climate, community, food insecurity, perception

INTRODUCTION

Since the 1980s, it has become apparent that our planet has been undergoing significant climate change due to human activities (IPCC 2007; Srivastava and Rai 2012). Paavola (2005) has documented that climate change affects livestock distribution and productivity, the prevalence of (vector-borne) livestock diseases, and the quantity and quality of rangeland (IPCC 2007). In addition, millions of people in East Africa and the horn of Africa (Eritrea, Djibouti, Somalia, Northern Kenya, Northern, and Southern Sudan) face climate-related hunger; the shifting seasons are causing widespread hunger; a warning that could reverse 50 years of ending poverty (Agrawala et al. 2003). Tanzania has great impacts: the melting icecap and glacial retreat at Mount Kilimanjaro (Luhanga et al. 1998); experienced 1997/1998 El Niño, which led to drought and flooding, skyrocketing food prices, and the loss of crops and cattle (US National Drought Mitigation Center 1998); and destructive flood in Kilosa District in January 2010 (Daily News 2010). Tanzania will significantly impact rain-fed agriculture and food production, shorten the rainy season, increase crop losses, and reduce water availability, affecting livelihood, health, and food security (Hunter-gatherers are included). Also, the frequency and intensity of bushfires shifts in the geographic distribution of plant and land cover (Mwandosya et al. 1998), which account for 90% of total energy (Paavola 2005).

In Tanzania, three ethnic groups are categorized as hunter-gatherers: Sanjos in Ngorongoro and Serengeti Districts, Sandawe in Kondoa District, and Hadzabe in Iramba, Mbulu, Karatu, and Meatu Districts. The societies' mode of subsistence involves hunting animals, fishing, and gathering edible plants, mobile habitat due to their reliance on a given natural environment. Their land can sustain the population densities of agriculturalists (60-100 times) more than the uncultivated hunter-gatherers (10-30 individuals). Their settlements may be temporary, permanent, or a combination. They also have non-hierarchical, egalitarian social structures; thus, wars are common and are usually caused by grudges and vendettas instead of territory or economic benefits. Archaeological and ethnographic reveal that hunting is a man's job while gathering wild fruits and vegetables for women, except for the Aeta people of the Philippines, where 85% of women hunt. They are not able to store surplus food (IDC 2007).

Hunter-gatherers (Hadzabe) comprise about 0.3% of the Iramba and Mbulu Districts; the other ethnic groups are Nyiramba, Nyaturu, Taturu, Barabaig, Sukuma, and Iraqw. Furthermore, about 90% of people living on a subsistence lifestyle in Iramba and Mbulu Districts depend on wild animals and fruits, crops, livestock, and crafts for food and income; the Hadzabe could be the most susceptible ethnic group to climate change impacts because their sustainability is highly affected by climate change (Ihucha 2008). For example, an analysis report (IDC 2007) in Munguli village reported water and food shortages that they were to eat uncommon food due to climate change

(IDC 2007).

Tanzania's regional report on livestock and harvest loss by 10% because of drought and floods. According to Ihucha (2008), hunter-gatherers face food shortages due to depending on fruit-gathering and hunting down wild animals. The prominent effect in Mbulu and Iramba includes the District's shortened and erratic rain seasons; for example, in Iramba 1984, drying of formal water sources, plant and animal diseases, and recurrent hunger were increased reported (IDC 2008). According to (MDC 2009), the Mbulu District and NGOs such as FARM-Africa are to solve the problem of food insecurity and water shortage in Yaeda valley. However, despite the government and NGOs' efforts to assist hunter-gatherers, scanty information (specifically the Hadzabe) about awareness, food availability, and act to disclose strategies used. This study is due to continuous climate change and limited information on how hunter-gatherers are affected in the Iramba and Mbulu Districts.

Several initiatives have been undertaken; policies, strategies, and programs were implemented on poverty reduction and food security. Although all the programs are solving non-hunter-gatherers problems and leaving behind Hadzabe, any effort on Hadzabe coping strategies in Iramba and Mbulu Districts will impact household food security, poverty reduction, and environmental conservation, not only generate comprehensive information, but also it would document the livelihood of Hadzabe about problems and solutions that would be useful to the government, development partners, and other relevant stakeholders in improving local coping strategies, reducing insecurity and poverty.

Specifically, the study would find out: (i) To establish Hadzabe's perceptions on climate change. (ii) To identify Hadzabe's food insecurity coping strategies toward climate change. (iii) To assess the extent of food stability and availability in Hadzabe

MATERIALS AND METHODS

Description of the study area and location

The study was managed in Kirumi and Haydom Divisions in Tanzania in Iramba and Mbulu District Councils (Figure 1). The study area lies between longitudes 34° and 35° and between latitudes 4° and 4°3″. The study area was bordered by eight Districts as follows, to the east are Babati and Hanang, and to the north are Karatu and Meatu.

Yaedachini ward in Haydom Division and Mwangeza ward in Kirumi Division were purposively selected for this study because Hadzabe people only live in these Wards. Five villages were involved in the study, three from the Yaedachini ward and two from the Mwangeza ward. The villages are Yaedachini, Mongo wa Mono, and Domanga in the Yaedachini ward and Kipamba and Munguli in the Mwangeza ward. The ethnic group of Hadzabe is click-speaking hunter-gatherers who mainly occupy northern Tanzania, an area within the lake Eyasi basin (Madsen 2000). Their territory traditionally extends over four administrative regions: Manyara, Singida, Arusha, and Shinyanga. In recent years, in terms of numbers and density, their coverage of the Yaeda Valley and Kideru Ridge above the valley in the Iramba, Mbulu, and Karatu Districts has increased (Levin 2005).

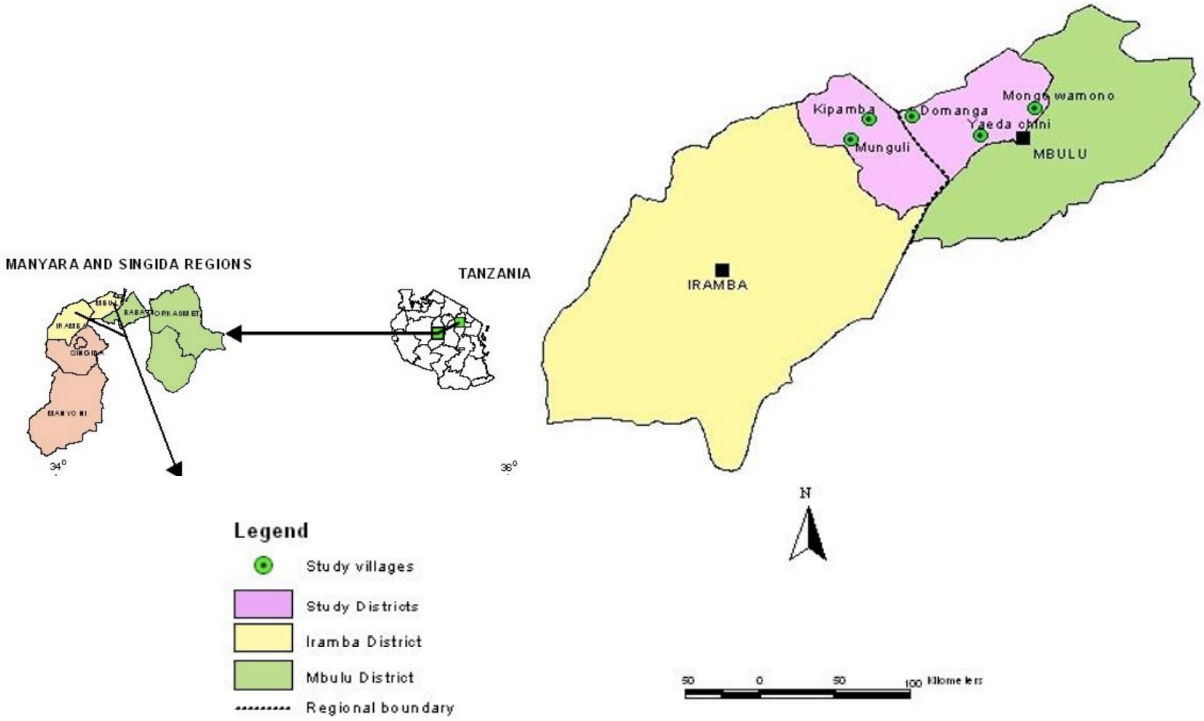


Figure 1. Map of Tanzania showing the study area

Geographically these areas have diverse landscapes. The Eyasi basin is typically semi-arid to arid with little rainfall (less than 400 mm per year), mean temperatures of 30^{O}C, and a terrain characterized by sandy soils and rocky that are very poor for agriculture (Levin 2005). The Hadzabe population ranges between 1,300 and 1,500 people within a traditional area covers approximately 1,500 square kilometers (Madsen 2000).

Research design

The method used for collecting data was a cross-sectional design. According to Babbie (1990) and Bailey (1994), a cross-sectional design could use minimum time and resources and allow data to be collected at a single point without repetitions from a sample selected representing a large population. This study's design was favorable because of limited resources like time, transport, and labor (personnel).

Sampling procedure

Sampling unit

The population involved in this study was Hadzabe in Iramba and Mbulu Districts. The main target groups of the sampling unit were the head of households due to the most appropriate in assessing the society's level and standard of living (Blackwood and Lynch 1994), which provides substantial information related to the objectives of this study.

Sample size

The study sample comprised 100 respondents, and 10 key informants were used to supplement the information.

Sampling method

The purposive and Simple Random Sampling (SRS) techniques were used to get the required sample. First, the respondents were selected from the list of members using a simple random technique. Then, the purposive sampling technique was used to obtain the desirable population to obtain 5 villages, three from Mbulu District and two from Iramba District. Moreover, as it focuses directly on the study's intended area, this purposive technique has generally been recommended in social science research (Kothari 2006).

Data collection procedures

Primary data

A questionnaire with open-ended questions and a checklist was used in the household survey, focus group discussion, and key informants interviews. Supplementary information, on the other hand, was collected through personal observation. The information gathered through interviews with key informants gave insights into the community-wide aspects of risks, coping strategies, and public responses to disasters.

Key informant interviews

Local and older people were involved in the research; the questions reflected perceptions of climate change and major climate change trends. In addition, there are ten key informants interviewed for each village.

Focus group discussions

Discussions among the focus group members were held around specific topics, including coping strategies, support networks, wealth ranking, environmental changes, sources of income or support, and hunting-gathering practices. Furthermore, to express their views, the discussions allowed different groups (e.g., women, the elderly, and recent immigrants to the village). Therefore, the group of 5-6 persons was organized and considered appropriate for discussion. During wealth ranking in the study area, the communities identified three major social-economic groups based on different activities and assets. These major social-economic groups include poor, medium, and rich.

Individual interviews

Structured questionnaires and semi-structured interviews were conducted with questions relating to livelihoods, informal institutions, community interactions, and coping strategies. Informal interviews carried on between one and two hours and were usually conducted in Kiswahili language at either the village compound or the respondent's compound. In addition, several interviews were conducted using a translator from the Hadza language (language spoken by Hadzabe) to Kiswahili.

Personal observations

Observations were conducted purposely with the assistance of one experienced or knowledgeable person who understood the social settings and livelihoods performed in the village. That is a social and environmental method for understanding the distribution of households, resources, and activities undertaken. Among the aspects involved in personal observations are the types of food eaten, housing, and daily activities.

Secondary data

An extensive review of secondary data was used, especially previous studies or research and from many reports on Hadzabe in Iramba District and Mbulu District. In addition, secondary data were collected through informal discussions with staff and officials in Iramba and Mbulu Districts Council, consulting on relevant publications to the study from Sokoine University of Agriculture National Library (SNAL), and the internet.

Data management procedures

Data processing

The primary data sources were summarized, edited, and then coded before entering the computer program.

Data analysis

Data analysis was done using contents analysis and Statistical Package for Social Science (SPSS) program. First, a theme wrote up notes taken during the interview for each case as part of the analysis. Next, descriptive statistics such as percentages and frequencies were described. Finally, the relations between variables pairs were determined through bivariate analysis, including cross-tabulation.

The study objectives were analyzed following analytical tools as follows: In establishing the perceptions of the community on climate change, descriptive statistics were used; descriptive statistics and cross-tabulation were used in identifying hunter-gatherers' food insecurity coping strategies toward climate change, and descriptive statistics and cross-tabulation were used in assessing the extent of food stability and availability to hunter-gathers.

RESULTS AND DISCUSSION

Background variables of respondents

This section discusses the respondents' demographic background variables, including age and sex, and social factors, including marital status, education, and household size. These variables were analyzed and discussed below in the sub-sections.

Demographic variables of the respondents

Age

The individual's age can influence productivity because the ability to conduct daily economic activities, farming and non-farming, will decrease with age. Therefore, age is the primary basis of demographic classification in vital statistics, censuses, and surveys, which is an important demographic variable (NBS 2005). The findings revealed that among the 100 respondents, the respondents ranged from 20 to 80 years old. Moreover, about 75% were particularly between 20 and 49 years old, 14% between 50 and 59 years old, and 11% between 60 and 80 years old (Table 1). According to Madulu (1996), the productive age economically ranges from 16 to 64 years old. The age groups below 16 and those above 64 are considered economically less productive due to having a high dependency ratio age structure. The ages also play a role in livelihood and coping strategies in Hadzabe village toward food security. It was reported that the age between 18-40s years old is the best age for hunting and gathering. The age above 60 was the technical age for training the young generation on hunting techniques. However, children also contributed up to 10% of collected fruits at home during fruit season.

Sex

Sex is a basic and important population characteristic for planning, labor division, and administration from household to national levels. The majority (68%) of the respondents in the Hadzabe area were males, and the remaining 32% were females (Table 1). This high male proportion was interviewed, as opposed to females, because males are heads of household in the Hadzabe tradition. The males were most likely to be interviewed, therefore, simply because the sampling unit was the head of the household, and the males were the heads even though females did many activities. As Mushi (2000) observed, the researcher aimed to interview the head of the household in cases where both a wife and a husband were available, and the husband was interviewed.

In the Hadzabe villages, the pattern of gender roles was such that women dug tubers and gathered fruits while men mostly hunted animals and collected honey. Because of climate change, some activities which used only to be done by men are currently done by women, e.g., honey collection. On the contrary, some activities done by women are currently also taken over by men, e.g., fruit gathering. However, raising kids is still done by women for biological reasons, which Marlowe (2005a) has contended. Therefore hunting remains for men because of reduced animal availability near the homestead, and many activities conducted near the homestead are left to women.

Socio-economic variables

Education

The education level is an important factor in coping with climate change-related disasters, particularly coping with risks and uncertainties related to food production. Regnar et al. (2002) consider the ultimate objective of education to increase labor productivity. Thus, it is a productive force for human beings and thus very important for their ability to efficiently utilize the information and advice offered by extension service providers and other development agents. The respondents' proportion with primary school education (standard 1-7) was 31%, 65% of the respondents had not gone to school, and a few (4%) of those interviewed had completed secondary school (Table 1). The study findings revealed that most households in the study area have no formal education, which is important in the fight against poverty. Any innovations uptake for issues on new technologies or good management practices will raise household resilience toward the hazard. The Hadzabe sluggishness in the study area in changing their lifestyle could be attributed to a lack of formal education among the residents.

Marital status

Marriage affects the production process as it increases labor availability in the household through sharing activities between husbands and wives and among other family members (Mtama 1997). The finding of this survey (Table 1) shows that 82% of women were married. Conversely, the entire household heads were either widowed, single, or divorced, representing 13%, 3%, and 2%, respectively. Therefore, the proportion of married respondents was greater than that of the other categories. This result seems higher than those reported by the Tanzania Demographic and Health Survey (TDHS 2005) and the National Bureau of Statistics (NBS 2005). According to those two data sources, about 66% of women in economic activities are married, lower than this finding at 82%; because family commitment implies that marriage influences daily economic activities. Moreover, as opposed to that reported by Tanzania Demographic and Survey, the high percentage of married women in the study area could be a good strategy imposed by Hadzabe to ensure that more food is brought home to cope with the food shortage. Marlowe and Berbesque (2009) reported the same result, revealed that Hadzabe, married and/or with a biological child ≤8 years old at home, takes significantly more daily kilocalories of food to camp than a single person without young biological children.

Table 1. Distribution of respondents according to sex and demographic variables (n=100)

Variable	Male	Percentage	Female	Percentage	Total	Percentage
Age						
20-29	11	11	11	11	22	22
30-39	17	17	10	10	27	27
40-49	18	18	8	8	26	26
50-59	12	12	2	2	14	14
60-69	7	7	1	1	8	8
Above 70	3	3	0	0	3	3
Total	68	68	32	32	100	100
Marital status						
Married	57	57	25	25	82	82
Single	3	3	0	0	3	3
Widowed	7	7	6	6	13	13
Divorced	1	1	1	1	2	2
Total	68	68	32	32	100	100
Education level						
None	42	42	23	23	65	65
Standard 4	4	4	3	3	7	7
Standard 7	19	19	5	5	24	24
Secondary school and above	3	3	1	1	4	4
Total	68	68	32	32	100	100

Household size

A group of related or unrelated people answerable to one person referred to a household is often regarded as the household head. The household members share a residential unit or structure and have the same housekeeping arrangements (Nduwamungu 2001). The household members may be related, unrelated, or both, usually including a husband, children, the wife, and other relatives. In this research, the household size was categorized into three groups (Table 2), which are 5, between 5 and 10, and above 10 members. About 35% of the respondents had households below 5 members, 63% between 5 and 10, and 2% above 10 members. The minimum and the maximum number of people observed per household were 2 and 10, respectively (Table 2), with an average household size of 5.

The survey found the household average size is 5 members, which is relatively smaller than the figure stated in the URT (2005), at an average of 5.1 members in the Iramba District Council, while the average household size in Tanzania stands at 4.9; rapid assessment undertaken suggested that a family with more than 6 people is a big family. In addition, Nduwamungu (2001) reported a strong relationship between household size and resource exploitation because large households often over-exploit natural resources to meet their basic needs (Madulu 1996). From the study area, however, since the number of people per household is small, it was revealed that household size has no impact on Hadzabe's livelihood. So, naturally, the birth rate is very small, and no resources are over-use.

Establishment of perception on the observed pattern of rainfall variability

Furthermore, group discussions and individual interviews were held to clarify the study area's perceptions of climate and climate change. The major focus of the discussion was on how people understand and define extreme events (floods or droughts). The groups and individuals were supposed to characterize their answers. For example, bad years in terms of weather have been reported to be on the rise; the reasons given include desertification due to increased human activities (farmers and pastoralists), particularly forest clearing for the following reasons; (i) Increased grazing area (more livestock) and (ii) Expansion of agricultural activities. On the other hand, good years have decreased due to recurrent and frequent droughts. That is because the rain rarely comes on time. Furthermore, it has been stated that during the prolonged rainy season, wild-fruit disease increases, but this needs to be examined to establish the association with climate variability. Table 3 summarizes the opinions of the focus group members.

The descriptions are given in terms of good or bad years; to the Hadzabe, a good year means no severe diseases, rain is reliable, and a high number of Hadzabe coming from other villages. A good year is characterized by plenty of water and food and people having health conditions. A bad year is characterized by severe hunger, the prevalence of human diseases, and water scarcity at water points. Hadzabe is aware of rainfall variability, as shown in Table 3.

During bad years, some households sell their labor to community workers or neighboring farmers (Sukuma and Iraqw), such as building schools, roads, and agricultural activity. Also, they sell their few assets to buy food. The sold assets were mostly bicycles, radios, and goats. Moreover, it has been reported that some conflicts emerge during bad years because some people move into their area with their livestock in search of pasture land and for growing crops. That leads to conflicts between farmers and hunter-gathers because farmers clear the bush (food reserve) for crop production.

Table 2. Distribution of respondents according to the village and household size (n=100)

Household size	Kipamba	Munguli	Yaedachini	Mongo wa Mono	Domanga	Total percentage
Below 5	8	9	6	7	5	35
5-10	12	11	13	12	15	63
Above 10	0	0	1	1	0	2
Total	20	20	20	20	20	100

Table 3. Description of good and bad years and their characteristics

Season variables	Characteristics
Good year	
Rain starts early and rains for a long time	Rain starts early and rains for a long time Vegetation/trees sprouting earlier leads to plenty of food in the jungle
Absence of water shortage	Enough water for livestock and domestic use
Absence of severe diseases	People are healthy
High number of immigrants	More food in the village
Bad year	
Severe hunger in the village	Poor, less food in the jungle
Human diseases (Malaria, typhoid)	Very hot, and much a water
Water is scarce	Low rainfall, very high temperature

Table 4. Trends and patterns of climatic events

Parameter	Frequency	Percentage
Perception of observed pattern of rainfall variability		
Yes	94	94
No	6	6
Total	100	100
Mentioned climate change vents within 10 Years		
Drought	89	89
Floods	11	11
The most common rainfall variation experienced		
Delay in rainy season	38	38
Early rainy season	1	1
Little rainfall	57	57
Do not know	4	4
The impact experienced from rain variation problem		
Drought	62	62
Hunger	33	33
Early food recovery	1	1
Do not know	4	4

Local perceptions of climate and climate change

During the discussion with Hadzabe, it was revealed that good years in climate are becoming less. Generally, extreme events occurrence and rainfall variability are more pronounced concerning the onset and cessation of the rainy season, the magnitude of drought and flood events, the number of rain days, and rainfall intensity. The results presented in Table 4 indicate that 94% of the respondents have experienced rain-oriented problems, while 6% have not experienced any rain-related problems. In the study area, the most common rain variations experienced include delays and decreases in the rain and early rainy season. Approximately 57% of the respondents indicated decreases in rainfall per season, 38% indicated a delay in rain season, 4% did not know anything about climate change, and only 1% indicated the early onset of rains compared to past decades. However, in the study area, drought followed by the flood was specified by 89% of the respondents as a serious problem, and 11% mentioned floods (Table 4).

It was reported during the discussion that floods, as opposed to drought, have a little negative impact on Hadzabe in the study area; the reasons given are that floods increase the amount of water in the soil and water points (the place for trapping and ambushing animals). Furthermore, tubers increase in size in the uplands by their quality and quantity due to the sufficient moisture in the soil; thus, tubers can not easily shrink and become bitter during the dry season; also, the flood makes some berry trees bear fruits twice a year. The study reveals that 94% of the respondents of different sex, ages, and education levels have experienced climate change and its variability. Therefore, the household head's age, education, and sex have no significant impact on people's perception of climate change because, naturally, climate change variability to Hadzabe involves feeling and observation.

Description of major climatic events and their associated impacts in the study area

Based on the descriptions in Tables 3 and 4, hunter-gatherers could map out bad years in climate and the associated impacts. Table 5 shows summarize major climatic events obtained in the study area.

The most famous events that Hadzabe remembered were the great famine that occurred due to prolonged drought in 1983/1984 and heavy rainfall in 1998, which could represent the indicators of climate change in the study area. Table 5 shows the major impacts of climate change on livelihood activities, and they complained that their way of life had changed. More specifically, gathering food and hunting activities have been affected. Moreover, due to drought, wild food is increasingly becoming scarce and unpredictable, hence people's movement to other places in search of food (foraging migration). Migration is sometimes temporary since people move during bad years and come back during good years. As shown in Table 5, hunger and disease prevalence are escalated by an extreme change in the rain regime. Therefore, weather change has a big impact on hunter-gatherers' livelihoods.

Table 5. Major climatic events and their associated impacts in the study area

Year	Event	Impact
1983-1984	Drought	Great famine. Wild animals shifted to water points. Many people died and migrated
1998	Too much rain (El Nino)	Plenty of tubers, specifically to uplands
2002	Early rain season	Early food recovery (tubers, fruits, and honey).
2003	Drought	Hunger, people migrated to other places
2006 and 2009	Drought	Hunger influx of pastoralists and farmers to our villages often leads to conflicts.

Major socio- economic livelihoods

Several studies have indicated that poverty levels among communities in the villages are well determined by the social or wealth status of the groups and have well-established relationships concerning livelihoods when the impacts associated with extreme events such as floods or drought occur. For example, according to Yanda et al. (2005), during a food shortage, poor people in the villages normally sell labor to the rich to sustain their livelihood in exchange for an income or a payment in kind. Therefore, in this study, the identification of different socio-economic groups per village was important to; (i) determine their vulnerability to climate change and variability and (ii) establish how different social groups cope with climate change and variability.

The main socio-economic undertakings in the study area are divided into three major groups: hunting and gathering, farm-related, and non-farm-related. All farm activities in the study area by Hadzabe were at a rudimentary stage. Thus, modern animal and crop husbandry techniques were still neglected. Table 6 indicates that 54% of the respondents were still committed to gathering and hunting, 42% were farmer-hunters-gatherers, 3% were committed to beekeeping, and 1% were working as civil servants.

Due to physical and social constraints, there have been several other non-hunting-gathering income-generating activities in the study area. Minor activities mentioned during the group discussion include petty business (kiosks and selling honey) and commitment to cultural tourism for some villages in the study area. Although cultural tourism is increasingly becoming a source of income for the community, Dorobo Safaris (Tourism Company) has established temporary camps for tourists at Mongo wa Mono and Domanga villages. At these camps, Hadzabe can exhibit their culture and take photographs with tourists on payment. Nevertheless, the tourism sector is still seasonal and affected by a low tourist flow into the village.

According to elders and village leaders, immigration is more common than emigration in the study area. The immigrants come from different places and are either permanently or temporarily settled, depending on the cause of their migration. For example, it was revealed that Hadzabe from Karatu and Meatu Districts have been migrating to Mongo wa Mono and Kipamba villages, the reason for migrating being hunting and gathering because their former domicile areas have been changed to either game-controlled areas, tourism hunting, or other investments. The new ethnic groups, likewise, Nyisanzu, Sukuma, and Iraqw, have been coming and permanently settling in these areas for farming, which were reported as the change agent for Hadzabe culture. The Barbaig, apart from that, for many decades was cited as a native ethnic group in the study area; the difference between the two groups resides only in their livelihoods. Hadzabe is a hunter-gatherer, while Barabaig is a typical pastoralist.

Hadzabe's wealth status

The well-being of the head of the household reflects the resilience level against food shortage in rural areas. Classifying an individual's well-being is an arbitrary exercise; therefore, it depends on criteria set by a particular community. The communities identified three major social-economic groups based on different assets and activities in the study area. Several factors were considered in identifying the major socio-economic groups, and these include: (i) the amount of livestock a person owns (goat, sheep, or chicken); (ii) the farmland size a person owns and uses; (iii) food security situation (sustainability and amount); (iv) the types and number of the house(s) a person has; (v) the types and number assets a person has (mobile phone, bicycle, and radio); (vi)the amount of money a person has at the time. Table 7 shows that most of the population owns few resources during wealth ranking. Therefore the types of activities (Figure 2) performed and assets owned by individual households are extremely weak to cope with climate change. Weak asset resource to hunter-gatherers was explained by the fact that to keep, no anybody is either allowed to keep or eat domesticated animals because of taboo beliefs. And also, engaging in agriculture and keeping animals were reported as tedious activities compared to hunting and gathering.

Figure 2. A poor maize farm managed, exemplifying the poor contribution of agriculture to Hadzabe's livelihoods

Table 6. Distribution of activities performed in the study area (n=100)

Activity	Kipamba	Munguli	Yaedachini	Mongo wa Mono	Domanga	Total percent
Beekeeper	2	1	0	0	0	3
farmer-hunter	0	15	20	3	4	42
Hadzabe	18	3	0	17	16	54
Civil servant	0	1	0	0	0	1
Total	20	20	20	20	20	100

Table 7. Contemporary wealth status in the study area

Major criteria	Rich	Medium	Poor
Amount of livestock a person owns	3 goats and chicks	2 chicks	owns 0 livestock
Amount of money (Tshs.) a person has at a time	20 000	3 000	<2 000
The size of farmland a person uses	2 acres	0.5 acres of farmland	Has no farm
Food security	Has food that suffices 10 months and above in the year	Has food for sufficing for 6 months	Has food, suffice only 3 months
Number and type of house(s) a person has	Has a house made by mud bricks roofed with mud (tembe) sometimes corrugated iron sheet	Has house made of mud	Owns a house thatched entirely by grass.
Number and types of assets A person has	1 bicycle, mobile phone, and radio hand hoe	Has radio and hand hoe,	Arrows and bowls

Division of labor among Hadzabe

The Hadzabe are not territorially based, and people are free to move wherever they please, though a core group tends to rotate through the same sites. It was revealed during a group discussion that the Hadzabe men mostly hunt mammals and birds, collecting honey and fruits, while women dig tubers and gather fruits. Furthermore, it was observed that girls normally, on the nature of hunting and gathering, collect wild fruits and vegetables with their mothers. However, young boys occasionally accompany their mothers and sisters and contribute much to the family food stock. Kajembe and Munyikombo's (1998) study also reported that a big percentage of women (46%), followed by children (28%), are involved in collecting wild food, followed by men (19%). Few Hadzabe is trying to engage in agriculture, despite its poor performance (Figure 2). Since agriculture was still a new activity to Hadzabe, there was no clear division of labor.

Status of food insecurity in the study area

Chronic food insecurity was observed in the study areas, which is a long-term or persistent food shortage; which is occurs when the Hadzabe are unable to meet their minimum food requirements over a sustained period, and it is caused by a lack of assets, an extended period of poverty, and inadequate access to financial or productive resources (FAO 2006). The food insecurity types were determined by asking the respondents about food shortages. The results in Table 8 show that 77% of the respondents frequently experience food shortages. In comparison, 22% indicated that food shortages were not happening yearly, and 1% of the respondents were food secured.

Furthermore, 76% of the respondents face food shortages between 3-5 months annually, and 16% and 8% showed food shortages between 6-7 months and 0-2 months annually, respectively. In the study area, this food insecurity could be attributed to some households having a high dependency on natural resources affected by current climate change. Conversely, the households indicated to be food secure in the study area were those whereby one of the household members is either a civil servant or the entire household is engaging in agriculture. Therefore, the above findings suggest that the population in the study area has chronic food insecurity.

Food security at the household level is affected by the composition and quality of the daily meals and the quantity and seasonal availability of staple food in the jungle. Food shortage in the study area starts in July and ends in February, the following season. Most households prone to food shortage depend solely on hunting and gathering. The mentioned months of plenty foods are March to June annually. The reason is that in March, the berries start ripening, while in May and June, honey harvesting starts and reaches its peak in July. Further reported that the honey sector was affected by climate change in two ways: the honey harvesting time is altered because of the unpredictable rainy season, and the amount of honey has declined over the past decades. The decreasing amount of honey production could be explained by the reduction in water and plant flowers which are the main honey ingredients.

Coping strategies against food insecurity

Coping strategies are the ability of people, households, and communities to withstand adverse circumstances. Food coping strategies are divided into three categories: economical, social, and environmental. For every category, the discussion is based on Table 9.

Table 8. Critical months of food shortages per year in the study area

Variables	Kipamba	Munguli	Yaedachini	Mongo wa Mono	Domanga	Total percent
Months of food shortages per year						
0-2	4	1	0	0	3	8
3-5	11	19	20	9	17	76
6-7	5	0	0	11	0	16
Total	20	20	20	20	20	100
Availability of food in the jungle						
Often	19	12	6	20	20	77
Sometime	1	7	14	20	0	22
Not at all	0	1	0	0	0	1
Total	20	20	20	20	20	100

Table 9. Distribution of food coping strategies of hunter-gatherers toward climate change (n=100)

Coping with food shortages	52	52
Relying on food from the government, NGOs, etc.	6	6
Eating food that has not been used before		
Migrate	17	17
Food borrowing from relatives and selling labor	20	20
All of the above	1	1
Selling off some of the assets	4	4
Total	100	100

Social strategies

The social response to food shortages includes labor sharing; gift or loaning food, livestock, or cash; and sometimes sending members of a distressed family to live with more fortunate friends or relatives (Zinyama 1987). Table 9 shows about 52% of the respondents reported reliance on food from the government and NGOs as a social strategy. Furthermore, the NGOs and government established a time frame indicating when hunter-gatherers become prone to food shortages yearly. Principally, the food shortage in the study area starts in December and ends in February

Economic strategies

Strategies for coping with food insecurity include the diversification of economic activities regarding animal ownership, hunting and gathering, and both off-hunting and non-hunting supplements to household income. The petty business was another important coping strategy for food shortage in the off-hunting and gathering activity mentioned above. Table 9 shows the reported prominent petty businesses in the study area, which involved the sale of honey and running small shops (kiosks 10%, and selling of assets (4%). The assets sold include chicken, small ruminant animals, and cultural tools like bows and arrows, which portray their culture to tourists for payment. The Hadzabe who manage the petty business are those living with another ethnic group (farmers); for example, in Yaedachini village, the Hadzabe living with other tribes have adopted the culture of other ethnic groups. This association between non-hunter-gatherers and Hadzabe indicates that hunter-gatherer coping strategies depend on non-hunter-gatherers and therefore implies, despite the differences in their livelihood, that it is difficult to isolate Hadzabe from other non-hunter-gatherers communities.

It was further noted that all the fruit trees in the study area were indigenous. Baobab, for example, was reported to be a source of income by hunter-gatherers, especially during the dry season. Kajembe and Munyikombo (1998) reported a similar result, which stated that wild products play a direct and indirect role in food security and that the direct role is consumption. The indirect role is selling to generate income for other expenditures.

In the context of this study, borrowing is a kind of informal food loan among households. The households with food surplus (non-Hadzabe households) give food to food-deficient ones with the expectation of repayment. In the study area, 20% were borrowed (Table 9). Borrowing is done in an agreement between Hadzabe and farmers. Depending on mutual agreement, repayment is generally done, and most of the food used to repay includes wild meat and honey.

Environmental strategies

The environment in this context means forest resources and their components. In rural Africa, wild foods provide a variety of vitamins and minerals. Wild foods are important as a main or supplement in times of food scarcity and daily diet (Ngana 1983). In addition, when they are collected and sold, it would provide an opportunity to generate income. Due to climate change, in food shortages, wild foods are used as a coping strategy for rural communities.

In the study area, the Hadzabe depend on wild food; if any changes in wild food due to climate change impact their daily life. Table 9 shows that 17% of Hadzabe people were reported to have migrated to areas where there is enough wild food and 6% of the respondents reported eating wild and other foods which they have not been used to before of food due to the scarcity resulting from climate change. The Hadzabe people that migrated to the area first went to demarcated villages for the Hadzabe in Kipamba and Mongo wa mono villages. The government purposively demarcated these villages as the sole villages for Hadzabe. To stress the importance of forest resources to hunter-gatherers, Marlowe (2006) contends that the environment is a main source of food and provides about 95% of the Hadzabe. Moreover, grain food, for example, was among the mentioned food not eaten by Hadzabe for the past decades. However, the Hadzabe are forced to eat such

foods due to difficult face circumstances. Also, fishes, amphibians, immature and pregnant animals, and reptiles were not eaten when food was scarce due to customs reasons, but nowadays, these items are increasingly becoming common. While these provisions are usually eaten when there is a shortage, they demonstrate the Hadzabe coping strategies.

Age was reported to play a big role in environmental coping strategies. For example, the active age for hunting was reported to be between 18-40s years old. Hunting performed by the Hadzab could be due to the type of livelihoods, which involved long-distance scavenging for food in the jungle for those superb ages. According to Blurton et al. (1989), grouping the population into an economically active and inactive population is arbitrary; it excludes many children who participate in the family's labor force. Older people (above 40s years old, Figure 3) were reported to be important in teaching such techniques as ensnaring animals and identifying sites for hunting and gathering because of their experience. Therefore, an individual's age plays a big role and depends on environmental support.

In coping with food strategies, gender also was reported to play a big role. Although 32% of the Hadzabe interviewed (Table 1) were female, there was evidence of high responsibility of females in day-to-day household activities such as house building, children caring, collecting berries and baobab, and other foraging activities except hunting which males do. A female in the study area plays a big role in the family food collection. Nevertheless, the major determinant of gender roles is essential food accessibility in the forest.

Livelihood activities adapted

Due to climate change, the Hadzabe, to a certain extent, have adapted to more new livelihoods now than in the late 1990s. However, it does not mean those changes on specific individuals or classes of people specializing in a particular activity. Individuals can undertake anything from hunting to gathering and farm to non-farm activities. There are several non-hunting-gathering-related incomes generating activities in the study area. Table 10 indicates that 63% of the respondents have at least participated in agriculture as a livelihood. On the other hand, 10% have engaged in petty business, 10% in livestock keeping and crop, 9% never adopted any, 7% were keeping bees, and only 1% adopted livestock keeping.

A surprising observation from the study area was that, though Hadzabe doesn't like to eat crops and grow them when there is a food shortage in the jungle, they do go out to sell their labor to nearby farmers (Iraqw and Sukuma) to get grain food for sustaining their family living. Another amazing thing is that cultivators and animal keepers surround the Hadzabe; most hunter-gatherers have, until recently, refused to take up agriculture because it would involve much hard work. When one of the Hadzabe questioned about taking agriculture as a solution to the food crisis; the response was, "When there are so many ekwa (*Vignia frutescens*) and kongolobe (*Grewia bicolor*) in the forest gifted by God, why should we plant?"

The slight changes observed from dependency on hunting and gathering to other non-hunting activities could be attributed to climate change. The other reason could be explained in the Hartmann theory, which explains "the hunter versus farmer" that most or all humans were nomadic hunter-gatherers for many thousands of years. Still, this standard gradually changed as agriculture developed in most societies, and more people worldwide became farmers. Changes in the human population, over-killing of animals, and environmental change due to human activities and climate change caused a decline in the availability of wild foods; therefore, people adapted to another way of food production (agriculture started). They expanded into lands traditionally used by Hadzabe as the number and size of agricultural societies increased. Many groups of hunter-gatherers in the world have perpetually declined partly due to pressure from growing agricultural and pastoral communities. The hunter-gatherer societies either adopted these practices or moved to other areas as a result of the competition for land use

Moreover, Hartmann speculates that the transition from hunting and gathering to agriculture is not necessarily a one-way process; people with Attention-Deficit Hyperactivity Disorder (ADHD) retained some older hunter characteristics. It has been argued (Winterhalder 1981; Marlowe 2005b) that hunting and gathering represent a coping strategy that may still be exploited if necessary; when environmental change causes extreme food stress for agriculturalists, for instance, they may also regularly hunt and gather. People in developed countries hunt primarily for leisure (Winterhalder 1981; Marlowe 2005b).

Figure 3. An old Hadzabe woman whose role is to teach scavenging techniques to the young generation

Table 10. Distribution of livelihood activities adapted by hunter-gatherers toward climate change (n=100)

Livelihood activities adapted	Respondents	Percent
Petty business	10	10
Small-size farm (0.5-2 acres)	63	63
Livestock keeping	1	1
Beekeeping	7	7
Crop and livestock	10	10
Not adopted any	9	9
Total	100	100

Assessment of food availability and stability

The Hadzabe were asked to mention their food and rank their food preference to establish food availability and stability, regardless of how genetically or culturally influenced, are integral to maintaining an adequate diet in any particular environment (Marlowe 2006).

The most preferred food is meat, reported by 52% of the respondents; grain food 24%; wild tuber 12%; honey 9% and baobab 3%. However, their preferred food is not eaten frequently due to the seasonal nature of its availability. For example, honey is available only for 3 months annually, from April to June. Table 11 shows the accessibility of food was reported to be another source of food shortage; about 64% responded that they never ate the preferred food frequently, while 36% eating frequently were those from villages that had adopted grain food. Therefore, the poor accessibility of food could be explained because wild food is fewer, and animals have shifted to far-protected areas because of the effect of climate change.

Food availability

Food availability addresses the supply side of food security and is determined by the food production and stock level (FAO 2006).

The observation result from the study area shows that the wild food availability has been reduced, and the reason for the reduction in amount was given. About 52% of the respondents indicated an increase in Hadzabe competing for the same resource, 37% even thought the reason was less rain in the area, and 11% thought it was because of environmental degradation by farmers and livestock keepers. Figure 4 indicates that due to drought, large game animals, like buffalo and giraffes, have shifted to the protected game reserve such as the Ngorongoro conservation area and Serengeti national park. Another reason is an increase in the human population. According to Hadzabe's custom, large animals' meat is used for paying dowry. Therefore, the unavailability of large animals has not only affected the food stability of Hadzabe but has also obliged the marriage system to change. Table 12 indicates that 40% of the respondents eat wild tuber frequently as opposed to other types of food, 19% eat baobab, 16% grain, 14% game meat, and 11% eat honey as an alternative food. The comparable percentage of food eaten as an alternative food indicates the level of food availability and accessibility to the Hadzabe. Therefore, the reason for less availability of food could be attributed to the fact that wild food is fewer and animals have shifted to far-protected areas because of water shortage in the former territory exacerbated by climate change. Wild tubers, biologically tolerant of drought, are increasingly becoming the main dish of the Hadzabe instead of meat and honey because such food items are abundant in the bush compared to other types of wild food.

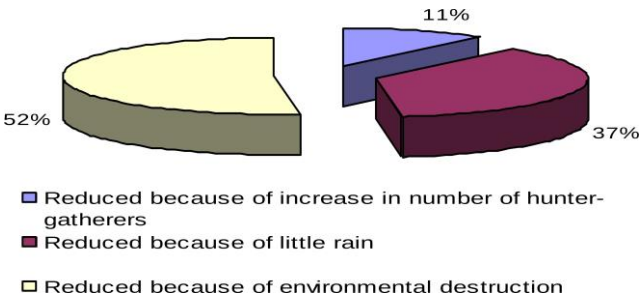


Figure 4. The main causes of food shortage in the forest

Table 11. Distribution of respondents' food preference and accessibility from gathering and non-gathering activities (n=100)

Variable	Kipamba	Munguli	Yaedachini	Mongowa Mono	Domanga	Total percent
Preferred staple food						
Baobab	0	0	0	1	2	3
Grain food	0	8	10	0	6	24
Wild tuber	6	0	1	1	4	12
Game meat	11	12	4	17	8	52
Honey	3	0	5	1	0	9
Ability to eat the preferred food						
Yes	0	17	12	2	5	36
No	20	3	8	18	15	64

Table 12. Distribution of respondents' alternative food eaten (n=100)

Alternative food eaten	Kipamba	Munguli	Yaedachini	Mongowa Mono	Domanga	Total percent
Honey	5	3	0	1	2	11
Wild tubers and berries	6	5	7	8	14	40
Baobab	3	4	3	9	0	19
Game meat	6	7	0	0	1	14
Grain food	0	1	10	2	3	16

Figure 5. Level of food instability in the hunter-gatherers' area

Food stability

Stability refers to the availability of food to all people at all times. Figure 5 shows that there was a food deficit in the study area. About 63% of the respondents faced a food shortage of between 3-4 months, 26% faced between 5-6 months, 7% faced between 1-2 months, 3% faced between 7 months and above, and 1% indicated not to have faced food shortage. Furthermore, food insufficiency was reported as a common phenomenon to the Hadzabe, which explained the instability status of food and was justified by 1% of the respondents who reported self-sufficiency.

According to FAO (2006), the main cause of food instability in the horn of Africa is the persistence of drought caused by climate change. Therefore, food instability in the study area could be accelerated by the impacts of the nature of the Hadzabe livelihoods in that they depend on hunting and gathering and climate change. As Marlowe (2006) asserts, about 80% of the food (berries, honey, and tubers) of the Hadzabe is obtained from gathering wild food and hunting, which is only 20%. Food gathering was reported to be highly affected by a change in the rain regime caused by climate change and, thus, to be seasonal biased. From March to June (berries and honey), food is plenty, while food is insufficient from August to February. Additionally, the Hadzabe, like other hunter-gatherers in the world, neither preserve nor store food for the future, and this habit demonstrates the food instability nature of the Hadzabe.

The institutions and their roles in the study area

During interviews and discussions, important major institutions which operate in the study area were identified, as shown in Table 13. The mentioned institutions play a big role in Hadzabe's coping strategies, especially during unfavorable events. However, villages in Mbulu District are more favored by institutions than Iramba District's geographical features and position of the study area. The institutions which operate in Mbulu District are Oxfam Africa, Hay dom hospital, Dorobo safaris, Olson Company, religious institutions, and Mbulu District council. On the other hand, Iramba District reported two institutions assisting the Hadzabe in the study area: Iramba District council and Hay dom hospital. These institutions are the key players in Hadzabe's coping strategies.

Table 13. Major institutions and their roles in the study area

Institution	Major role
Olson Company (Hay dom)	Deals with the supply of food on behalf of the government during critical periods
Iramba and Mbulu District Councils	Constructing primary and secondary schools and providing food during the critical period
Religious institutions Generally	Assist in spiritual matters
Dorobo safaris	Remitting food and clothes and cultural tourism to Hadzabe

REFERENCES

Agrawala SA, Moehner A, Hemp M, Aalst S, Hitz J, Smith H, Meena SM, Mwakifwamba, Mwaipopo OU. 2003. Development and Climate Change in Tanzania: Focus on Kilimanjaro. [www.icid18.org/files/posters/13/1277889551.doc] site visited on 30/3/2009.

Babbie E. 1990. Survey Research Methods. Wordworth Publishing Company, Belmont California.

Bailey DK. 1994. Method of Social Science Research. The Free Press Collier Macmillan Publisher, London.

Blackwood DL, Lynch RG. 1994. Measurement of inequality and poverty. Policy maker's guide to the literature. World Dev J 22 (4): 567-578. DOI: 10.1016/0305-750X(94)90112-0.

Blurton J, Hawkes KG, O'connell JF. 1989. Comparative Socioecology of Mammals and Man. [www.anthro.utah.edu/PDF/paper/hawkesetal97.pdf+blirton] site visited on 10/02/2010.

Daily News. 2010. Flood disaster in Kilosa and Shinyanga. Daily News. Issue No.9876. pp. 2.

Food and Agriculture Organization (FAO). 2006. Food Security Assessment Report in Developing Countries. [ftp://ftp.fao.org/es/ESA/policybriefs/pb/2001.pdf] site visited on 5/3/2010.

Ihucha A. 2008. Hadzabe Facing Severe Pressure on Traditional Way of Life: Indigenous Peoples of Tanzania. [http://www.ippmedia.com/ipp/guardian/2007/04/30/89471.html] site visited on 20/8/2009.

Intergovernmental Panel on Climate Change (IPCC). 2001. Third assessment report on the regional impacts of climate change: an assessment of vulnerability. [http://www.ipcc-wg2.gov] site visited on 27/3/2009.

Intergovernmental Panel on Climate Change (IPCC). 2007. Special report on the regional impacts of climate change: an assessment of vulnerability. [http://www.ipcc-wg2.gov] site visited on 20/3/2009.

Iramba District Council (IDC). 2007. Taarifa ya Hali Halisi ya Chakula Wilaya ya Iramba. Iramba, Tanzania.

Iramba District Council (IDC). 2008. Iramba District Development Profile. Iramba, Tanzania.

Kajembe GC, Munyikombo LZ. 1998. Magu District Agroforestry Project. Baseline Study report. Lantana, Nairobi, Kenya.

Kothari JZ. 2006. Research Methodology. Methods and Technique. Dharaush Printers Delhi India.

Levin A. 2005. Safari with the Hadzabe: Journal of African Travel. [http://www.leakeyfoundation.org/news&events] site visited on 13/8/2009.

Luhanga ML, Mwandosya MJ, Nyenzi BS. 1998. Vulnerability and Coping to Climate Change Impacts in Tanzania. Research Report Series.[http://www.southsouthnorth.org/download.asp?name=tanzania country report.pdf] site visited on 13/2/2009.

Madsen A. 2000. Hadzabe People of Tanzania: Land and Human Rights for a Hunter- Gatherer Community. [http://www.un.org/overview/rights.html] site visited on 3/8/2009.

Madulu NF. 1996. Environmental Degradation and Marital Fertility Change in Tanzania Kondoa District. [Thesis]. University of Dar es Salaam, Tanzania.

Marlowe FW, Berbesque JC. 2009b. Tubers as fallback foods and their impact on hadza hunter-gatherers. Am J Phys Anthropol 140: 751-758. DOI: 10.1002/ajpa.21040.

Marlowe FW. 2005a. Who tends hadza children? In: Hewlett B, Lamb M (eds). Hunter-Gatherer Childhoods: Evolutionary, Developmental and Cultural Perspectives. [http://www.anthro.fsu.edu/people/faculty/?marlowe] site visited on 10/3/ 2010.

Marlowe FW. 2005b. Hunter-gatherers and human evolution. Evol Anthropol J 14 (2): 54-67. DOI: 10.1002/evan.20046.

Marlowe FW. 2006. Central place provisioning: Hadza as an example. In: Hohmann G, Robbins M, Boesch C (eds). Feeding Ecology in Apes and Other Primates. Cambridge University Press, Cambridge.

Mbulu District Council (MDC). 2009. Mbulu District Development Profile. Mbulu, Tanzania.

Mtama LY. 1997. Factors on Fluencing Female-Headed Household Involvement in Sasakawa Global 2000 Project in Rukwa Region. [Dissertation]. Sokoine University of Agriculture, Morogoro.

Mushi SJ. 2000. Economic of charcoal production in miombo woodland of Eastern Tanzania. Some Hidden Costs Associated with Commercialisation of Resources. Ecol Econ 3: 243-257. DOI: 10.1016/S0921-8009(00)00196-8.

Mwandosya MJ, Nyenzi BS, Luhanga ML. 1998. The Assessment of Vulnerability and Adaptation to Climate Change Impacts in Tanzania. Centre for Energy, Environment, Science and Technology (CEEST), Dar es Salaam, Tanzania

National Bureau of Statistics (NBS). 2005. Research and Analysis Working Group. Tanzania Poverty and Human Development Report 2005. Mkuki na Nyota Publishers, Dar es Salaam, Tanzania.

Nduwamungu J. 2001. Dynamic of Deforestation of Miombo Woodlands: the Case of Kilosa District. [Thesis]. Sokoine University of Agriculture, Morogoro, Tanzania.

Ngana J. 1983. Rainfall and Agriculture Drought and Famine in Dodoma District. Research Report No. 60. Institute of Resource Assessment, University of Dar es Salaam. Dar es Salaam, Tanzania.

Paavola J. 2005. Vulnerability to Climate Change in Tanzania: Sources, Substance and Solutions. In: Proceedings of Inaugural workshop of Southern Africa Vulnerability Initiative (SAVI) in Maputo, Mozambique.[http://www.gechs.org/savi/workshop/maputo/papers/paavola_tanzani a.pdf] site visited on 2/03/2009.

Regnar O, Borchgrerink A, Lazaro E, Temu A. 2002. Poverty reducing effects of agricultural development in Tanzania. Noragric Report Number 10, December, 2002. Noragric Agricultural University of Norway. [http://www.nln.noragric] site visited on 12/11/2008.

Srivastava AK, Rai MK. 2012. Review: Sugarcane production: Impact of climate change and its mitigation 13: 214-227. DOI: 10.13057/biodiv/d130408.

Tanzania Demographic and Health Survey (TDHS). 2005. Tanzania Poverty and Human Development Report. Research and analysis working group Dar-es Salaam, Tanzania.

United State National Drought Mitigation Center. 1998. Reported Effect of the 1997-98 Eli-Nino. Lincoln NE, USA. [www.drought.unl.edu/risk/world/table2.pdf] site visited on 4/03/2009.

Winterhalder B. 1981. Optimal foraging strategies and hunter-gatherer research in anthropology: Theory and models. In: Smith EA (eds). Hunter-Gatherer Foraging Strategies: Ethnographic and Archaeological Analysis. University of Chicago, Chicago.

Yanda PZ, Kangalawe RYM, Sigalla RJ. 2005. Climatic and Socio-Economic Influences on Malaria and Cholera Risks in Lake Victoria Region of Tanzania. Working Paper No.12 June. [www.care.dk/multmedia/pdf/web-english/climate] site visited on 27/03/2009.

Zinyama LM. 1987. Rural household structure, absenteeism and agricultural labour: Case study of two subsistence farming areas in Zimbabwe. J Trop Geogr 7 (2): 163-17. DOI: 10.1111/j.1467-9493.1986.tb00180.x.

INTL J TROP DRYLANDS
Volume 6, Number 2, June 2022
Pages: 90-102

E-ISSN: 2580-2828
DOI: 10.13057/tropdrylands/t060205

Effects of climate-change variability on livestock production and coping strategies in Maikona, Marsabit County, Kenya

MOLU WATO[1], MICHAEL K. KOECH[1], JAMES N. MARAGA[2]

[1]Department of Environmental Education, School of Environmental Studies, Kenyatta University. Nairobi, Kenya. Tel: +254-20-870 Ext 4000/3000, ♥email: mi.koech@gmail.com

[2]State University of New York/Agile and Harmonized Assistance for Devolved Institutions. H. Carl McCall SUNY Building, New York, USA

Manuscript received: 3 September 2022. Revision accepted: 29 November 2022.

Abstract. *Wato M, Koech MK, Maraga JN. 2022. Effects of climate-change variability on livestock production and coping strategies in Maikona, Marsabit County, Kenya. Intl J Trop Drylands 6: 90-102.* Climate change is viewed as one of humanity's greatest challenges. This study sought to investigate the coping mechanisms pastoral communities have employed in Maikona Location (Marsabit County, Kenya) and their sustainability. The study employed quantitative and qualitative methods, targeting 145 respondents, including 127 household respondents, 14 Women and Youth group members in FGDs, and 4 technical/NGO representatives. Questionnaires, FGDs, and key informant checklists were the main tools. Data were analyzed both inferentially and descriptively. The study envisioned would give vital information to policy-makers and pastoral development stakeholders on the actual impacts facing the pastoralists and the existing and appropriate coping mechanisms while guiding the interventions and policy options. The study found that there had been real and perceived changes in temperature and rainfall patterns. Field inquiries indicated rainfall patterns significantly changed (94%) between 1980 and 2010, as well as a significantly declining trend of the data from the metrological department. These changes were established to negatively impact livestock production and the livelihood of the community in the study area. The local community was found to seek relief food, buy food on credit and sell livestock assets as common coping strategies. The sustainability of those strategies, however, is in immense doubt since most of the respondents were not even sure of their longevity, while others admitted they might not use them for long. Moreover, most (84%) of the respondents could not tell the consequences of their strategies on the environment. The external supports provided to the communities were largely in response to emergencies and were not viewed as sustainable in the long term. The study recommended constantly sharing rainfall data from the metrological department with the pastoralists to understand the dynamics of rainfall and temperature variations on livestock production and possible coping strategies customized for their situation and advise them on sustainability. The study further recommended the need for long-term support like establishing a livestock market, supporting education through sponsorship, and adopting policies that support mobility instead of sedentarization of the communities.

Keywords: Climate change, communities, livestock, Maikona

INTRODUCTION

Climate change has been defined as a significant variation of the mean state of climate-relevant variables such as temperature, precipitation, and wind over a period, mostly taken over 30 years (IPCC 2007; Srivastava and Rai 2012). Global climate change is a major threat that is greatly facing humanity. According to Intergovernmental Panel on Climate Change (IPCC 2007), climate change has increased global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level. At continental and regional levels, numerous long-term changes in climate have been observed. They include the widespread changes in precipitation amounts and distribution, wind patterns, ocean salinity, and aspects of extreme weather resulting in heavy precipitation, heat waves, droughts, and the intensity of tropical cyclones. These changes threaten community ecosystems, livelihoods, and social groups (Watson et al. 1998; O'Brien and Leichenko 2000). As a livelihood option, the agriculture/Livestock production sector is one key sector that will bear the brunt of climatic changes.

Africa is one region where the effects of climate change are being felt particularly hard. Because of the lack of development, economic, and institutional capacity, African countries are supposed to be among the most vulnerable to the impacts of climate change (IPCC 2001). Therefore, climate change impacts can undermine and even undo the progress of Africans in improving their socio-economic well-being, including East Africans (WWFN 2006). In addition, many factors, including human diseases, widespread poverty, and high population density, also compound the negative impacts associated with climate change. For example, the increasing population pressure is estimated to double the demand for food, water, and livestock forage within 30 years (Davidson 2003).

Arid and Semi-Arid Lands (ASALs) and the poor are the most vulnerable and likely hardest hit by climate change due to their low adaptive capacity (IPCC 2001). Globally, those risks threaten around 70% of rural people living in extreme poverty (OECD 2001). Moreover, despite their low contribution to greenhouse gases, developing countries are experiencing the adverse impacts of climate change. Therefore, climate change seriously threatens the livelihoods and food security of millions living in Africa's

arid and semi-arid lands (WWFN 2006). That is because the agricultural systems and food production in Sub-Saharan Africa (SSA) primarily rely on climate-sensitive rainfall (Ketiem et al. 2009). The region's climatic data analysis shows that rainfall coefficient variation in semi-arid tropics can be as high as 50%. In contrast, most annual rainfall often falls in a few rainfall events within three to five months. Therefore, predictions indicate a more severe crop production decline is expected in many parts of Africa, leading to malnutrition, insecurity, hunger, and migrations (Ketiem et al. 2009).

The ASAL areas face several challenges, including the impacts of climate change. According to KARI (2004), one of the main challenges facing the ASALs ecosystem is enhancing communities' resilience, in which their livelihoods entirely depend on climate-sensitive resources. The vulnerability of pastoralists is escalating due to increasing population growth, recurrent natural disasters, and the declining carrying capacity of the land. The general agreement is that pastoral areas face an increased drought risk due to high temperatures and increased rainfall variability (IPCC 2007). Climate change impact has pushed many of the households in the ASALs to resort to several coping strategies. Moreover, many pastoral households have resorted to settling near trading centers and water points to access relief food and water without burdening their beast burdens to seek casual employment and allow easy movement of their herds. However, the failure of such coping strategies might endanger the pastoralists' survivalists. Some fear that pastoral livelihoods, especially in East Africa, are already rapidly becoming more unsustainable than other forms of rural livelihood (Morton 2010). The pastoralist might therefore be in danger of being the first environmental refugees. More research on the impact of climate change is needed for the pastoral system (DFID 2009).

Thus, this study is an effort aimed at reducing this gap by looking at the specific impact climate change has on the livelihoods of the pastoralists and what they do to cope as well as analyzing the effect of those coping mechanisms.

MATERIALS AND METHODS

Geographical features of the study site

The Maikona location is within the Chalbi desert basin in Kenya, below 600 m asl (Table 1). Therefore, the rainfall in the study area is usually unreliable, erratic, and highly variable in space and time. However, rainfall is the most important climatic factor affecting biological productivity and the widespread residents' economy. Though quite unpredictable, the area receives a bi-modal rainfall pattern averaging about 200-300mm per annum. The area's average temperature is about 30°C (Climate-Data.org 2015).

Design and locale of the study

The exploratory study employed both qualitative and quantitative methods, using the cross-sectional survey approach. The major study focused on assessing climate change has impacted the livestock production system and the coping strategies nature employed by pastoralists concerning the impact of climate change. Further, this study examined the sustainability of coping strategies employed. The study site was the Maikona location of Marsabit County, chosen because it is largely a pastoral district and is believed to give a good insight into the impact of climate change on the pastoral livestock production system. Therefore, this specific site was the Maikona sub-location. The study was conducted in villages around the Maikona trading center, whose geographical coordinates range from 2°54'02.30"N to 2°57'16.70"N and 37°37'55.40"E to 37°40'03.60"E.

Study population and sampling procedure

The study was conducted in the Maikona location of Marsabit North District. A total of 145 respondents participated in the study, including 127 household respondents, 14 Women and Youth group members in FGDs, and added with 4 technical/NGO representatives. According to the 2009 census data, Maikona had 1,265 households. Therefore, the households acted as the sampling frame. The researcher sampled 10% of the study's total households following Mugenda and Mugenda's (2003) sample determination. The 10% samples were taken to translate to a sample of about 127 households in three village clusters, as shown in Table 1, which were selected using systematic random sampling.

The quantitative data was collected by the pre-determined household interview schedule, while qualitative data were captured using key informant interviews and Focus Group Discussions (FGD). The heads of each household were the main respondents. In case the heads were unavailable, interviews were presented by the senior most adult. The researcher also interviewed selected purposive key informants, namely the Metrological Department officer, Arid Land Resource Management Officer, Livestock production officer, and a Pastoralist Community Initiative Development and Assistance (PACIDA) officer as an NGO representative. Besides the key informants' interviews, the researcher also conducted Focus Group Discussions (FGDs) with members of the pastoralist households. Youths (both females and males) and adult females were mainly targeted in the focus group discussion to incorporate their views because household heads, though as respondents for the household questionnaires, were expected to be mainly male adults. The groups had at least six members to enhance openness considering homogeneity in each group. In addition, secondary documents were reviewed to triangulate and compare the emerging issues. The secondary documents reviewed included documentaries, previous studies, and program reports by non-governmental and governmental bodies.

Table 1. Village clusters and the number of households sampled

No.	Village clusters	Number of respondents
1	Oromo Gala/Katello Demo	46
2	Guyo Roba	41
3	Diba Okotu	40
Total		127

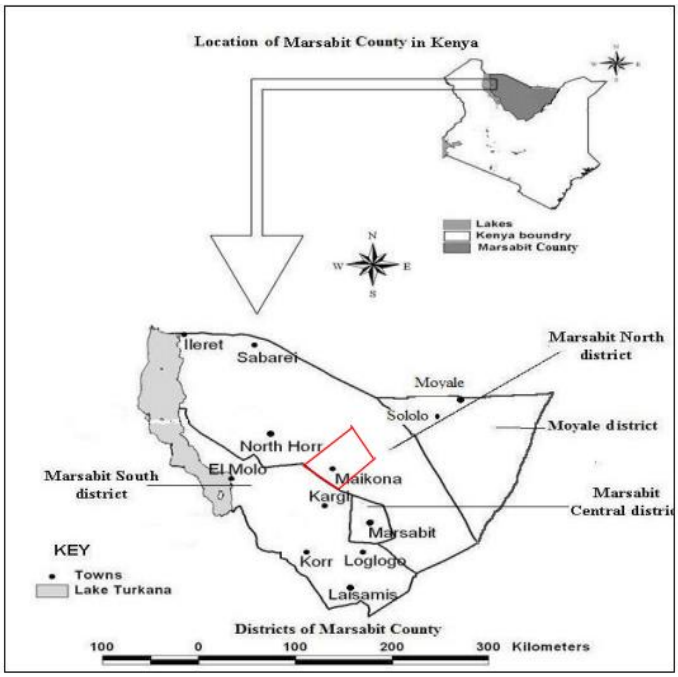


Figure 1. Map showing the study area in Marsabit County concerning Kenya (Waweru 2010)

Research instruments

The questionnaire was the main tool used to get views of the pastoralist households to gather information. At the same time, the Focus group discussion checklist helped gather information from the groups, mainly through historical resource trends, resource trends analysis, and problem analysis. A key Informant checklist was also used to gather information from officials of the Meteorological Department, the Ministry of Livestock, and NGOs. At the same time, a documentary review of climate change parameters was done.

Data collection

The collected data included; the traditional weather patterns of the area, historical climatic variables (temperature and rainfall) trends, the trend of the priority livestock numbers as an indicator of production within the last ten years, the awareness level of the pastoralists about the changing climate, the nature and types of the impacts the changing climate variability has had on the priority species livestock production and the coping strategies employed by the pastoralists in a reaction as well as the presence of external support to help the pastoralists adapt to the impacts of climate change.

Data analysis

The questionnaire data were coded, tabulated, and analyzed using Ms excel. The data collected from the officials and key informants were widely analyzed descriptively to align with the research questions. The analyses were used to portray statistical and descriptive inferences. Descriptive statistics were computed to establish the percentage of the responses, and the coefficient of correlation was computed to assess any relationship between livestock production and climatic variables of temperature and rainfall. The analyses result were presented using cross-tabulation tables and graphs (mainly line and bar).

RESULTS AND DISCUSSION

This chapter presents the interpretation and analysis of data collected during fieldwork. The interpretation and analysis are completed within the framework of the core objectives that the study sought to address. The respondents included members of selected households, the Meteorological Department, Livestock production officers, and local NGOs (PACIDA and Care Kenya). Data presented in this study are organized into four themes based on the key research questions that guided fieldwork, which were trends and patterns of temperature and rainfall, the effect of variability in climate parameters and on livestock production, coping strategies employed by the pastoral households, and the sustainability of those coping strategies. This study proceeded in different phases, and the first phase sought to establish the demographic and social characteristics of the respondents.

Demographic characteristics of the respondents

This section presents some of the demographic aspects of the respondents. Accordingly, the main demographic features of the respondents featured in this section include: the gender, occupation, and level of education of respondents.

Distribution of respondents by gender

The researcher found it important to establish the gender proportions of the respondents, and the distribution pattern is presented in Table 1. As described in this table,

most respondents (76%) were men, while the rest (24%) were women. This gender distribution has a lot of implications for understanding the perception of men and women. Also, to understand between male and female members of pastoralist households, the nature of strategies used to cope with adverse weather changes.

Distribution of respondents by the level of education

The researcher sought to establish the level of education of the individual respondents to draw basic indicators of one's socio-economic status. This distribution pattern, presented in Table 1, clearly shows that illiteracy was overwhelmingly high at 95% in the research community, especially among adults.

Distribution of respondents by occupation

Another basic indicator of socio-economic status sought by the researcher using the questionnaire was the occupation of the individual respondents, which is presented in Table 1. Livestock rearing, which the respondents rely on, was reported to be the main occupation, with 93% (n: 127). Casual employment, Business, and those destitute relying upon only relief all at 2% of the respondents, while those in formal employment were only 1 %.

The researcher decided to get the gender dynamics of this occupation because livestock rearing is the predominant occupation. Table 1 shows that more males are involved in livestock rearing than females. However, the difference was possibly insignificant because all family members normally took joint responsibility for rearing their family stock.

Climate parameter variability and their effect since 1980 in Marsabit

The researcher sought to establish the trends and patterns of climate parameters (temperature and rainfall) and their consequences in Marsabit County in Northern Kenya since 1980. This section, therefore, provides the findings on this objective.

Trends and patterns of rainfall in Marsabit County

Respondents were asked several questions about rainfall patterns in the study site. One question was their opinion if there had been changes in rainfall in recent years.

A clear majority of the respondents (95%) confirmed that there had been some changes in the rainfall patterns, while a minority (21%) could not verify whether there had been changes (Figure 2A). The barrier in the interpretation of time and the use of different calendars may have made some respondents not comprehend the changes. Therefore, the researcher sought to find out the real nature of the changes in rainfall. Figure 2B illustrates the result when the respondents were asked to indicate the nature of the changes in the rainfall patterns.

Nearly all the respondents (95%) indicated that the pattern of rainfall decreased as opposed to only 5%, who indicated that the changes as an increase in the amount of rainfall, citing the rains in late 2011 as an example, which was actually outside the study period. In addition, the respondents cited evidence of persistent drought, with a good number putting the drought cycle at every two years.

Table 1. Respondent characteristics (n = 127)

Criteria		Percentage (%)
Gender	Male	76
	Female	24
Education	No	95.3
	Primary	2.4
	High school	0.8
	Tertiary	1.6
Occupation	Livestock rearing	93
	Employment	1
	bussiness	2
	Casual labor	2
	Rely on relief food	2
Gender of livestock breeder	Male	48
	Female	52

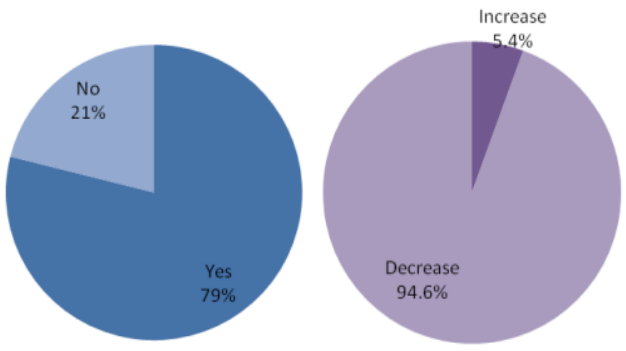


Figure 2. A. Changes in rainfall patterns in recent years. B. Nature of changes in rainfall

The respondents, however, seem oblivious to what caused the changes they experienced, as presented in Table 2. Most (38%) of the respondents negated knowledge of the causes of the changes they experienced. Similarly, a substantial percentage (20%) desperately answered that it was God's plan, and 12% thought it was God's punishment for persistent conflict and people's social ills. Furthermore, 10% thought that it was because the area is a desert and natural rainfall was scarce, and further desertification worsened the rainfall patterns. Only 2%, which was quite insignificant, thought the changes might be due to climatic change. That was an indicator of the community's poor awareness of the climate change facts that the world is grappling with the same problem.

To collaborate with the information from the pastoralists, the researcher sought rainfall data from the meteorological department and plotted it in Figure 3. The data revealed the rainfall pattern was changed slightly, which inclined towards a decrease. There is indeed a consistent pattern of decrease save for the 1997/1998 El-Niño rainfalls. However, it is worth noting that rainfall data are obtained from Marsabit metrological station, about 100

Km away from Maikona (since no such data are available at Maikona) but can indicate rainfall patterns for the entire area.

Impact of the changes in the rainfall pattern

As to the effect of change in rainfall patterns on their livelihoods, an overwhelming majority of the respondents (95%) answers were negative. These results are indicated in Figure 4. The majority of the respondents said that the change in rainfall pattern had a negative impact on them. They mentioned a reduction in pasture production, affecting livestock health and livelihoods. Furthermore, with each drought, the distance to water points was also reported to increase, taking distance for livestock and humans. As a result, during droughts, livestock dies, reducing their numbers and productivity, disrupting livestock breeding, and the numbers dwindle. During persistent droughts, the respondents reported relying heavily on relief food.

Trends and patterns of temperature in Marsabit County

Besides the rainfall issues in the study site, respondents were asked several questions on temperature patterns. One fundamental question was whether there had been changes in temperature patterns in recent years. Their responses were as presented in Figure 5.

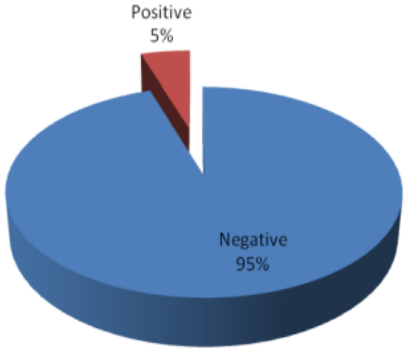


Figure 4. Response of impact of change in rainfall pattern

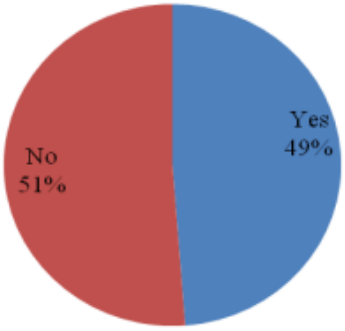


Figure 5. Changes in temperature patterns in the recent years

Table 2. Reasons for the cause of changes in the rainfall pattern in Maikona

Reasons	Frequency	Percentage
For decrease		
Don't Know	48	38
Weakening cultural practices	16	13
Existing desert and desertification	13	10
Social ills and Conflicts	10	8
God's plan and nature	28	20
Climate and weather changes	2	2
Strong wind and dust	2	2
Population increase& over-exploitation of resources	2	2
For Increase		
To save livestock and humans	6	5
Total	**127**	**100**

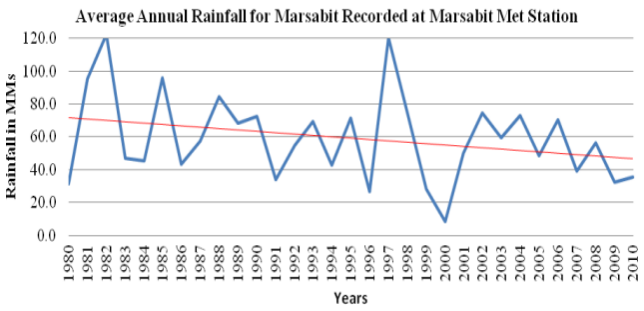


Figure 3. The trend in rainfall pattern in Marsabit between 1980 and 2010 (Source: KMD)

It could be concluded that half of the respondents (51%) said they had not noticed any changes in the temperature patterns, while 49% confirmed that t the temperature patterns had been changed. This disparity was not anticipated, and possible that the respondents may not comprehend or detect changes in temperature patterns. However, they complained that it was very hot those days, even during the interview. Nonetheless, the researcher sought to discover the real nature of the temperature changes. As a result, when those respondents who claimed they had experienced some changes were asked to refer to the nature of the changes in the temperature patterns, a whooping majority (97%) acclaimed to have experienced increased temperature, as indicated in Figure 6 below.

They gave the following justifications, shown in Table 3, when asked further to explain why they thought the temperature in the area was increasing.

As illustrated in Table 3, those factors could possibly increase temperatures as correctly perceived. Though the respondents answered them differently, many of their answers were fundamentally related. Therefore, they all agreed that there was extreme heat during the day. Some argued with cold nights, strong wind, and so on. However, most of the respondents did not exactly know when probed further about the possible cause of these signs and the increase in temperature, as evidenced in the answers tabulated in Table 4.

Most of the respondents (70%) could not tell directly what caused the temperature changes. In contrast, others allude to increases in the sunshine, degradation, drought, and people abandoning their culture hence being punished.

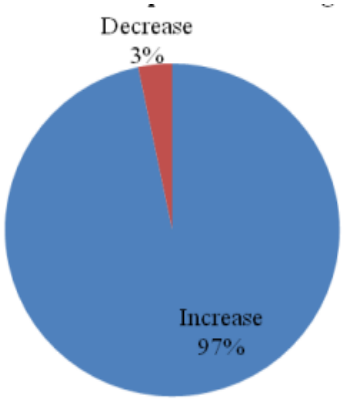


Figure 6. Nature of temperature changes

Table 3. Justifications for the nature of changes in temperature

Justifications	Frequency	Percentage
Heat all through	23	38
Extreme hot days and cold nights	18	29
Very hot during the day	8	13
Hot days with strong dry winds	9	15
Others	3	5
Total	**61**	**100**

Table 4. Reasons for temperature changes

Reasons for temperature changes	Frequency	Percentage
Unknown	42	70
Extreme sunshine	4	6
Drought	10	16
People abandoning culture	1	2
Land degradation	4	6
Total	**61**	**100**

Conventional temperature records

The researcher sought data from the meteorological department to understand the temperature trend in the study area. Though these data were obtained from Marsabit, the researcher believed that the data could give a fairly accurate regional trend. The trend in the temperature is shown in Figure 7A. A close look at this trend shows a marginally increasing mean annual temperature in Marsabit. However, as indicated in the trend line in Figure 7B, the average minimum temperature has increased by 0.6°C. That means the temperature is rising, which collaborates with the response by 38% of the respondents. Conversely, the trend in the average maximum temperature is nearly constant, as indicated in Figure 7C, thus bringing the trend in average annual temperature at a marginal increase of 0.6°C.

Impact of the changes in temperature levels

The researcher sought to investigate the impact of the changes in the temperature levels on the respondents' livelihoods after having established the perceived and real changes in temperature and possible reasons behind the changes. Most respondents (68%) indicated that the impact was negative, and a significant minority (32%) remained non-committal, whom the researcher concluded as lacking a clear understanding of the impact or question. Figure 8 below shows this response.

Interviews with the livestock production officer revealed that the impact was negative, though he could not provide formal data. As a community of pastoralists who entirely depend on livestock, the harsh or rather high-temperature levels made grazing difficult or disrupted the livestock feeding pattern, particularly during the day, reinforcing the responses of negative impacts. The high temperature was also unfavorable to pregnant goats, which many respondents claim caused miscarriage and premature births.

Climate parameter variability and livestock population

In the study area, the research also sought to examine the variability effect in climate parameters and pasture availability on livestock production. To achieve this, the researcher sought the respondents' opinions on the relationship between changes in their livestock production and the climatic variable of rainfall. Their responses are indicated in Figure 9.

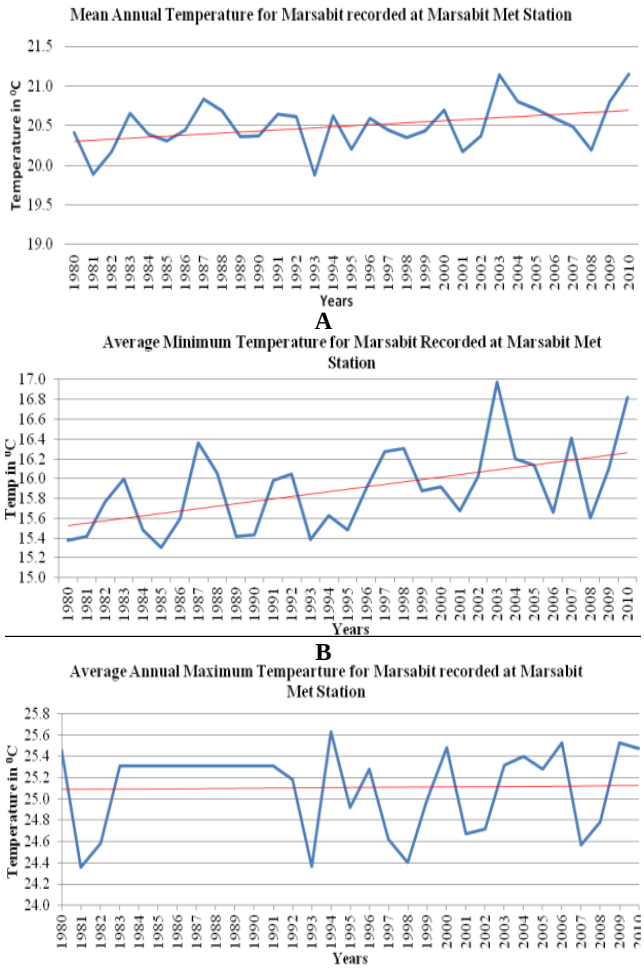


Figure 7. The trend in Marsabit between 1980 and 2010: A. temperature pattern, B. minimum temperature pattern, C. maximum temperature pattern (source: KMD)

Most of the respondents (92%) confirmed a relationship between changes in their livestock production and rainfall. Therefore, the researcher sought to find out from the respondents how the changes in rainfall affected livestock production. Among key issues raised were animals multiply during the rainy season, and increased rainfall increases livestock production, such as milk and meat. Conversely, during the dry season, livestock production reduces since the livestock population decreases because of extreme drought, less fodder, and heavy torrents kill livestock. Figure 9 shows the rainfall pattern from data obtained from Marsabit metrological station.

From the trend line, the pattern is a downward trend. Figure 9 shows that rainfall was highest in 1997/1998 during the El-Niño and lowest in 2000 during a severe drought in which the community reportedly lost many goats and sheep. The population trend for the area's three top-most priority livestock species was plotted to establish the trend and to compare with that of climatic parameters, as shown in Figure 10.

Figures 10 show that the population of goats remained nearly constant, with only a marginal decrease between 1981 and 2007. However, as the trend lines show, the decrease in the populations of camel and sheep is relatively rapid. Even though the population data obtained from the Ministry of Livestock Development is not specific to Maikona Location, for the former Marsabit district, it can be a good indicator of the trend of the livestock population in the area Maikona Location.

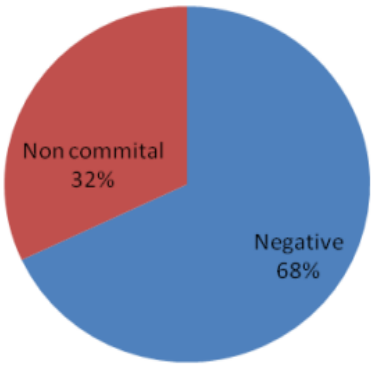


Figure 8. Impact of temperature change

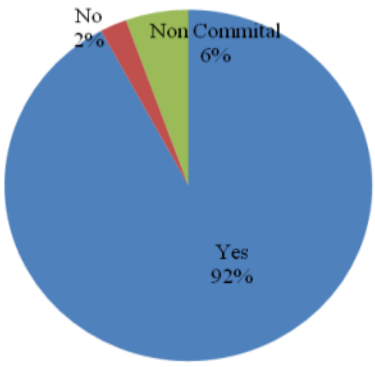


Figure 9. Relationship between changes in the production of your livestock and rainfall variation

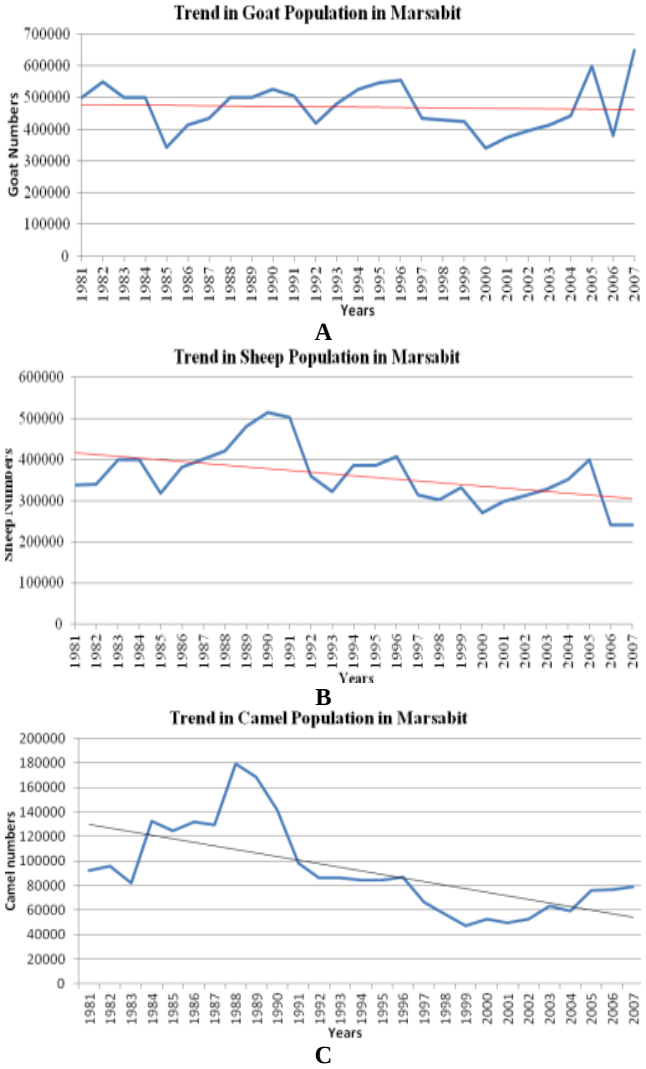


Figure 10. A. The population in the former Marsabit District: A. goats, B. sheep, C. camels (Source: MLD)

Therefore, the researcher envisioned making some conservative conclusions based on the data. Therefore, the population of sheep, goats, and camel in the study area is used since these three livestock types are the priority in terms of livelihood support for the community, as shown in Table 5. This table shows that the respondents' priority livestock types in livelihood support are sheep, the first priority at 80%, and goats, the second priority at 80%. In comparison, camel is the third most important livestock supporting community livelihoods at 79%. Therefore, the impact of the community's survival in the study area of climatic variables on these three most important livestock species is critical.

Relationship between climatic variables and livestock population

The researcher felt there was a need to determine the relationship between the climatic variables of rainfall and temperature and the three important livestock species. That would help establish whether the variations in livestock numbers were, indeed, a result of variations in climatic parameters.

Table 5. Priority response

Livestock type	Frequency	Percentage
1st livestock response		
Goat	10	8
Sheep	102	80
Cattle	0	0
Camel	10	8
Donkey	0	0
Others	5	4
Total	**127**	**100**
2nd livestock type		
Goat	101	80
Sheep	17	13
Cattle	0	0
Camel	2	2
Donkey	0	0
Others	7	6
Total	**127**	**100**
3rd livestock type		
Goat	8	6
Sheep	3	2
Cattle	6	5
Camel	100	79
Donkey	0	0
Others	10	8
Total	**127**	**100**

A closer look at the figures in Tables 8a and b reveals mixed relationships, which is not very obvious. However, in an actual sense, one would expect an obvious straight relationship between livestock population and those climatic variables. That may be attributed to the data quality, especially livestock data, due to the gaps and the fact that they were mainly estimates, even though some weak relationships can be observed. For example, the relationship between rainfall and goat and sheep population is weak and tends towards negative. One would expect this relationship to be strong and positive, but this is not obvious because the livestock population does increase even by a reducing margin as the human population owning the livestock increases. Again the rainfall measurement is confined to Marsabit meteorological station. At the same time, the livestock population is widespread, and due to the nomadic nature of the population, it may not be easy to correlate to the rainfall.

Nevertheless, the relationship between rainfall and camel population is positive, meaning that the camel numbers decrease and increase with rainfall. This trend is expected and may be accurate as opposed to goats and sheep since the camel population is not as naturally high as sheep and goats, and even small changes could be felt. Likewise, the relationship with temperature is not as straightforward as anticipated. Therefore, the researcher analyzed the relationship between the annual minimum, maximum, and average annual temperatures to enhance the actual position. Goats and camel numbers seemed to have a negative relationship with average annual temperature, which may be so because extreme temperatures do negatively affect livestock populations. On the other hand, the sheep population seemed to be more sensitive to minimum temperatures than the maximum.

Coping strategies to climatic parameter variations

This study was also attracted to coping with climate variability and pasture availability to establish the strategies employed by pastoral households. On this, the respondents were asked to indicate whether there were strategies they devised to survive or reduce the impact of climate variability. Their responses are captured in Table 9.

Asked which strategies they employed, the respondents outlined several strategies, among them separation of livestock herd, diversification of livestock herd, increasing mobility of livestock herd, migration to market centers/water points, buying/borrowing food on credit, reducing frequency/quality/quantity of meals, looking for casual employment, engage in small businesses, seeking relief food and remittance from relatives, seeking refuge in education, charcoal burning, change brewing, selling of household assets and livestock. The researcher went further to establish the three top most important priorities. According to the respondents, seeking relief food is the most important strategy at 45% (F: 57). Buying food on credit to be paid when the drought ends is the second priority strategy at 32%. In comparison, selling livestock, including lactating ones, is the third priority strategy at 28%. Other significant strategies worth mentioning are separating livestock herds, diversifying livestock species, increasing the mobility of livestock herds, and seeking casual employment around the trading centers. The result was tabulated in Table 10.

Table 8a. Livestock population and average annual rainfall Pearson(r) coefficient of correlations values

Livestock type	Pearson(r) values
Sheep	-0.0818261
Goats	-0.0232771
Camel	0.1588662

Table 8b. Livestock population and temperatures Pearson(r) coefficient of correlations values

Livestock type	Annual Min. Temp, Pearson(r) values	Annual Max. Temp Pearson (r) values	Ave. Annual Temp, Pearson (r) values
Sheep	-0.2232953	0.0994897	0.1175409
Goats	0.0049123	-0.0477104	-0.0962073
Camel	-0.4009187	0.0791865	-0.0695692

Table 9. Climatic variability coping strategy

Response	Frequency	Percent
Yes	125	98
No/Non-committal	2	2
Total	**127**	**100**

Table 10. Figures of the top three most important priority strategies

Coping strategies	1st Priority		2nd Priority		3rd priority	
	Freq.	%	Freq.	%	Freq.	%
None Committal	2	2	2	2	2	2
Diversification of livestock herd	15	12	8	6	2	2
Separation of livestock herd	20	16	6	5	5	5
Increased mobility of livestock herd	10	8	9	7	7	7
Migration to market centers/water points	7	6	0	0	0	0
Buying food on credit	2	2	41	32	16	16
Borrow food	0	0	2	2	0	0
Reduce the frequency of meals	1	1	0	0	3	3
Reduce the quality /quantity of meals	0	0	3	2	0	0
Rely on relief food	57	45	16	13	26	27
Rely on remittance from relatives	0	0	2	2	2	2
Seek refuge in education	1	1	6	5	3	3
Seek casual employment	9	7	11	9	4	4
Engage in small businesses	3	2	2	2	1	1
Burning of Charcoal	0	0	4	3	0	0
Sale of Livestock	0	0	15	12	27	28
Total	**127**	**100**	**127**	**100**	**98**	**100**

Table 11. Knowledge of the environmental impact of coping strategies

Response	Frequency	Percentage
Yes	20	16
No	107	84
Total	127	100

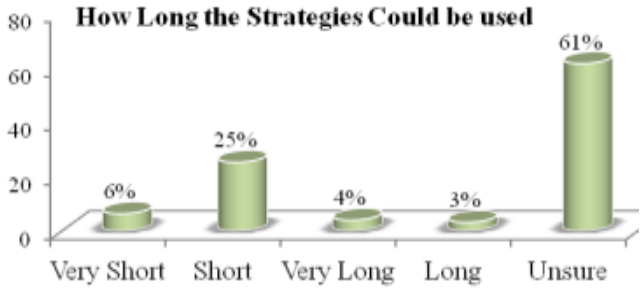


Figure 11. Duration for using the strategy

Sustainability of the coping strategies

Among the many ways sustainability has been defined, the simplest and most fundamental is "the capacity to endure." Sustainability is based on the simple principle that everything we need for survival and well-being depends directly or indirectly on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony that permit fulfilling the social, economic, and other requirements of present and future generations.

Duration of the coping strategies could be used

The researcher was therefore interested in establishing whether the coping strategies used by the respondents can remain in serving them. In this study, the respondents were asked to indicate the duration they thought they would continue using these strategies, whose responses were as shown in Figure 11 above. From the graph distribution, it was clear that the respondents were unsure how long they could continue using the strategies they indicated. A significant number, 61%, thought they might not use the strategy for long, while 25% thought it was short-term. Moreover, to probe deeper as to why they would want to use the strategies they had indicated, the respondents gave reasons like lack of education, decreasing number of livestock, persistent drought, lack of capital, unreliable relief, and the general uncertainty of the weather conditions.

Respondent's awareness of the environmental impact of the coping strategies

After a significant establishment of coping strategies that the respondents employ, the researcher sought to find out if they knew of any impact their coping strategy may have on the environment. Table 11 shows the distribution of their responses. From the distribution of these findings, it was clear that most (84%) respondents were unaware of any environmental impact of the copying strategies they employ in navigating climatic changes. That is, in a way, closely related to the profile of the respondents, especially the educational profile. Therefore, this may be an indicator of low environmental awareness and the level of consciousness.

Impact of the coping strategy on future survival

Furthermore, to cement the investigation on sustainability, the respondents were asked whether they knew if their coping strategy (ies) affected their livelihood/survival in the future in any way. About 64% indicated that they knew, while the remaining 36% maintained that they were unaware. Those again become an issue worthy of concern since most of the strategies employed have some impact on the residents' future lives, yet a substantial number were unaware. Nevertheless, a question was posed to those who responded whether they knew the nature of the impact and whether they were aware of the impact of their present strategy on their future livelihood. Out of these, 86% indicated that they thought it was negative, while only 14% indicated that they knew it would be positive.

Some explanations for the negative impacts of those scoping strategies include increased poverty as sources of livelihoods diminish during livestock sales, separation of the family when livestock move far away, and inaccessibility of livestock products such as milk during such times to distance. As nomadic pastoralists settle near water points or market centers to access water and food relief, nomadism dies out, leading to a high concentration of people around those centers, and causing land degradation. Borrowing food on credit plunges the pastoralists' family into a debt cycle and decreases family wealth, risking bad debts for the small kiosk owners. Moreover, since the majority rely on relief food as a strategy, it creates dependency, breaking down the community's livelihood system.

On the other hand, respondents have noted that settling around the market centers for relief food and water has offered them a chance to take their children to school, which will secure their education and extended family. Also, since they relied on the remaining type of livestock when one is affected by droughts, the diversification of livestock herds has helped some respondents sustain their livelihoods. On the other hand, increased herd mobility is reported to have saved some herds during extended droughts.

Constraints inhibiting the development of coping strategies

The researcher sought to establish the constraints that inhibit respondents from developing coping strategies to cope with climate variability trends. Their responses cited some form of inhibition to cope effectively (85%). They mentioned two main constraints: lack of capital at 59% and low level of education at 51% to set up more effective strategies. Other constraints they blamed include the nature of the land and their environment, old age, general body weaknesses, having young children that inhibit long-distance movements, and inability to move long distances due to disability. Others condemned having fewer numbers of livestock or poverty to support them cope effectively, while some widows felt they lacked adequate support to cope effectively on their own. The conflict between pastoral communities in far-flung reserve grazing areas was also blamed for undermining coping. It should be noted that they did not suggest the strategies they would have wanted to set up if had had their capital, or rather, the strategies they had that were hard for them to adopt because of the high expenses involved.

Existence of external support

The researcher sought to know whether there are official government departments or Non-Governmental Organizations that support or ever supported them to overcome the impacts of climate variability. A majority of them, 98%, confirmed their support, while 1.6% denied it in overcoming climate variability's impact. Since many of the respondents had indicated such support, they were asked to indicate the sources of this external support. Their responses are indicated in Table 12.

In this regard, respondents recognize the support from official government departments in helping them cope with extreme climatic conditions at 40%. The NGOs have also been mentioned to cope with the impact of climate change by giving support in helping the people in the study area. The most active NGOs were PACIDA, Christian Children Fund (CCF), Community Initiative Facilitation and Assistance (CIFA), and the Red Cross. The government departments mentioned as giving the most assistance include the Government department of ALMP (now NDMA), the Livestock department, and the Department of Veterinary Services. The department of livestock production and veterinary services combined were mentioned by many respondents, having most supported them, followed by the Office of the President (Provincial Administration) and the ALRMP/NDMA at 15% and 12% of respondents, respectively.

The researcher sought to find out the nature of the support given by the NGOs and the government departments. Respondents gave multiple responses indicating having received more than one form of support. The responses are presented in Table 13 below.

From Table 13, the main form of support given by the government and NGOs was either a food voucher, food relief, or cash relief, followed by destocking and vaccination.

Future strategies for reducing the impact of climate change

The respondents were asked about their opinion of the strategies that would be used in the future and which would reduce the climatic change impact. Their responses were as represented in Table 14.

Table 12. Sources of support

Supporting Institution	Frequency	Percentage
NGOs	74	58
Government Department	51	40
No support	2	2
Total	**127**	**100**

Table 13. Nature of support given by government departments

Nature of Support	Frequency	Percentage
Relief-Food Voucher, Cash relief, Nutritional Supplements	124	98
Destocking and Vaccination	49	39
Animal feed relief	42	33
Non-Food Items-utensils	12	9
Sponsorship of students in education	18	14

Table 14. Possible future strategies for reducing the impact of climate change

Strategy	Frequency	Percentage
Migrate out of the area	8	6
Abandon pastoralism	5	4
Diversify within pastoralism	20	16
Diversify economic activities	47	37
I don't know	47	37
Total	**127**	**100**

The responses depict, owing to the number of respondents unsure what to do (37%), that the community has probably been pushed beyond the limit or with very few options. The same number envisions diversifying their economic activities, but their options seem slim due to an unfavorable environment and poverty. A small number even indicate their despair at the thought of abandoning pastoralism. However, diversification within pastoralism was an option seen by those yet to despair at 16% of the respondents. Some ways suggested for diversification are adding more livestock species, separating the herd, and increasing the herd's mobility. The researcher is also very interested in those who wish to diversify their economic activities to survive the vagaries of the weather. Some options given included seeking casual employment, engaging in petty trade, and some unfavorable means like brewing chang'aa and burning charcoal. They thought these activities might help them survive. Still, the health issues and the acceptability of the chang'aa option were unresolved, while the environmental sustainability of charcoal burning in desert environments that have been degraded may not be feasible.

Suggestions on external intervention

The respondents were asked to indicate what they thought could be done to help them cope with climate change. In their response, they mentioned several suggestions, which include the establishment of stable livestock markets, restocking, enhancement of development activities for casual laborers, creation of more opportunities for casual employment, support education for their children, creation of awareness, especially on environmental conservation, continuous and adequate relief for both animals and people, the provision of water for animals in the areas with pasture and lack of water and awareness creation and capacity building on ways of coping with weather changes. Furthermore, now that mobility is part of the respondents' lifestyle, there were suggestions of support for mobility and continuous peace-building and conflict resolution among the communities.

Discussion

This section presents an interpretation of some of the remarkable findings of this study and its comparison with the limited data available in the area. The section is organized into four thematic areas based on the key research questions of the patterns and trends of rainfall and temperature, the effect of variability in climate parameters on livestock population, coping strategies employed by pastoral households, and an examination of their sustainability.

The gender respondents' composition may have some implications in understanding the nature of strategies used to cope with adverse climate changes. The study established that there were more male than female respondents. That may be influenced by the community's culture, where the male is the family head and is the official spokesperson on every matter, especially if the information seeker is an outsider. Since the pastoralists tend to their livestock as a family unit, however, the respondent's gender may not have much influence on the responses given in other sections. However, it is significant in the research community that illiteracy is overwhelmingly high among adults, consistent with the data from the Kenya Bureau of Statistics (Thornton et al. 2009). Therefore, it is worth recognizing that the level of education influences an individual's understanding of issues and access to information, including options available for adaptation and climate information to adverse climatic changes.

The predominant occupation of the respondents as expected was livestock rearing. However, that could be influenced by several factors, primarily the nature of the environment of the study site. Maikona sub-location is in the heart of the Chalbi desert. That makes farming and other livelihood activities difficult owing to the low precipitation, the rocky nature of the soil, high temperature, and soil salinity levels.

The respondents confirmed that there were changes in the rainfall pattern in the study area, and almost all of those respondents agree that the reduction is the changing pattern. However, the minority who responded to the changes manifested in an increase in the amount of rainfall cited as an example the rains in late 2011, a time which was actually outside the study period, which may be due to the barrier in the interpretation of time since the community uses a different calendar and unable to comprehend the instruction on the study time frame. Also, the persistent drought occurring every two years was cited as an indicator of changing rainfall patterns. This finding is consistent with the IPCC (2007) prediction. However, the respondents were oblivious to what caused the changes they experienced. This ignorance was an indicator of the community's poor awareness of the climate change issues that the world is grappling with, which could be attributed to a lack of exposure beyond their community boundary, the high illiteracy levels, and little understanding of the dynamics of climatic patterns, coupled with heavy reliance on nature and strong cultural ties. Indeed, the metrological data of rainfall obtained from the Marsabit Metrological station collaborated with the community's perception, showing a declining rainfall in the area though marginally. However, due to the lack of such services in Maikona, the data relied upon were collected about 100 km away, and it was believed that it could indicate the trend in the whole County.

According to a study by Witsenburg and Roba (2004) covering the period of 1920-2001, Marsabit and Moyale stations, from the long-term mean of 81 years, registered an annual rainfall deviating at least 75%. The study illustrates that Marsabit station registered a sharp fall in the annual rainfall during the last 40 years or so of the study period. Regarding the decadal differences, the rainfall between 1960 and 2001 shows a more proportionate decrease (relative decrease of 8.7% per year) than a marginal increase between 1919 and 1960 (at a relative rise of 2.5% per year), which would suggest a high possibility of reduced annual rainfall during the last 20 years relative to the similar earlier periods. The mean annual rainfall for Marsabit is 11 % below the overall average during the last decade. This decade also had the lowest average rainfall

compared to the other decades. Witsenburg and Roba (2004) concluded that Marsabit experienced lower average rainfall over 30 years than the previous 30 years during their study period of 1920-2001. Their study also concluded that the risk of adverse precipitation over the last 30 years was twice as high as over the previous 50 years. This result confirms respondents' popular view that: 'nowadays droughts occur more frequently" and/or "these days it rains."

The respondents clearly indicated that the rainfall change negatively influenced their livelihoods. The most outstanding effects were its reduction of pasture production, which affected livestock health, crashing the community's livelihoods. Distance to water points was reported to increase with each drought, increasing tracking distance for livestock and humans, affecting their health. Livestock dies during droughts, thus reducing their numbers and productivity. Moreover, livestock breeding is disrupted during droughts, and the numbers dwindle. That plunges the community into poverty and causes resort to relief dependency as the last recourse in the cycle. Witsenburg and Roba (2004) concluded that while the human population constantly grew between 1920 and 2001, the rainfall data and livestock numbers depict similar downward trends over time, especially during the last decade of that period, which collaborates with the finding of this study.

On the other hand, the respondents could not tell a temperature change because they could not physically detect changes in temperature patterns. It is possible that without an instrument, one may not tell a slight temperature change correctly. However, a whooping majority of those who thought to have noticed some changes claimed the temperatures were increasing, which collaborated with the notion of global warming, where the temperature was thought to be rising. The data from Marsabit Metrological Station also slightly validated the increasing temperature on average. However, the average minimum temperature has increased tremendously, which means indicated by the respondents, the area was becoming hot throughout.

However, the respondents could not tell what caused the temperature changes but alluded to reasons like drought, increase in sunshine, degradation, and people abandoning their culture hence being punished by God, indicating a low level of awareness about the climate change phenomenon. Generally, the respondents report experiencing negative impacts of increased temperature, though some of which were disruption of livestock feeding pattern or disruption of grazing, particularly during hot days, miscarriage, especially in small stocks, premature births, and even death of lamb and young kids during migrations. Scientifically, warming is thought to alter heat exchange between animals and the environment, and mortality, growth, reproduction, feed intake, maintenance, and production are all potentially affected (Thornton et al. 2009). Moreover, scientific records show that increased temperature has been linked to livestock mortality and reduced productivity (Thornton et al. 2009). It has also been shown that physical livestock activities decline during unusually high temperatures, including feed intake (Thornton et al. 2009). In addition, high temperatures and reduced feed intake put a ceiling on milk yield irrespective of feed intake, and in the tropics, this may be between half and one-third of the potential of modern cow breeds. Moreover, increased energy deficits may decrease fitness, fertility, and longevity (King et al. 2006).

As thought, the effect of rainfall on the livestock population was direct in the study area. Residents reported milk and meat production as one such direct relationship. It was also reported that livestock dies during prolonged dry spells and multiplies during favorable seasons. As established in the study area, the reduced rainfall pattern has caused a net decline in livestock numbers due to decreased forage. Livestock also did fetch poor prices during the frequent drought cycles reported. Consequently, it was revealed that the population of the three priority livestock has declined over the study period, with sheep and camel being the most affected. When livestock numbers declined, directly related to their production, it affected the pure pastoralists' livelihoods, affecting food availability and other needs. Therefore, it collaborated with the respondents' responses in the study area that changes in climatic variables have negatively impacted their livelihoods and that the quality of their lives was decreasing. Considering that the population in the area was increasing and that of their livestock was decreasing, therefore, it means that the residents were becoming poorer. This finding complies with existing known facts that precipitation reduces and temperature increases crop and reducing pasture yield. Rising temperatures and changes in rainfall patterns directly affect pasture yields (IFPRI 2009). The availability and quality of pasture directly affect livestock production in pastoral areas where the livestock purely depends on a range of resources.

Furthermore, to survive, it was established that residents devised several coping mechanisms with three top most important priorities: seeking relief food, buying food on credit to be paid when the drought ends, and selling productive livestock herds, including lactating ones. Unfortunately, the respondents were uncertain about how long they may continue using the strategies, and some of their top priority options seemed unsustainable. It is impossible to tell because they can't tell how long they may continue getting food on credit, or providing relief food may not be in their control. Even environmentally speaking, the residents could not tell the impact of what they were doing; all they did was just to survive by all means. That indicates a community with poor environmental awareness levels and/or a lack of viable means of survival. Indeed, the main impediments to adopting strategies were identified as lack of opportunities, lower education, decreasing livestock, persistent drought, financial capital, unreliable relief, and the general uncertainty of the weather conditions.

This study has revealed that the present coping strategies affected the target community's ability to adapt in the future in terms of an increase in poverty as sources of livelihoods diminish due to the sale of productive livestock, separation of the family when livestock move far away as well as the inaccessibility of the livestock products due to

distance. Furthermore, as nomadic pastoralists were settling near market centers/water points to access relief and water, nomadism was at risk leading to the high concentration of sedentary people around those centers, thereby causing environmental degradation. Furthermore, borrowing food on credit plunges households into the cycle of debts and erodes family wealth as families incur bad debts for the small kiosk owners. Moreover, since the majority rely on relief food as a strategy, breaking down the community's livelihood system due to creating dependency.

On the flip side, settling around the market centers to access water and relief offered the residents a chance to take their children to school, which secured the future of those children and the extended family. Also, diversification of livestock herds was helpful to sustain their livelihoods because different species were affected differently; since they relied on the remaining type of livestock when one was affected by the droughts, increased mobility of the herd was able to save some herds during extended droughts.

With the overwhelming effect of drought cycles, it was clearly established that there was external support from the government and NGOs. The main support identified included relief supplies, nutritional supplements, veterinary services, NFIs, and student scholarships. However, it was unclear how sustainable those supports were, especially with the dependency syndrome setting in. On their own, the community appeared with very few options or pushed beyond its limit. A sizeable number was unsure of what to do and required animation and propositions of well-researched options. A similar number envisions diversifying their economic activities, but their options seem slim due to unfavorable environments and poverty. A small number even thought of abandoning pastoralism, an indicator of despair. Some of the ways suggested for diversification within pastoralism included; adding more species of livestock, separating the herd and further increasing the mobility of the herd. The researcher also took a keen interest in those who wish to diversify their economic activities to survive the vagaries of the weather. Some options given included seeking casual employment, engaging in petty trade, and some unfavorable means like brewing chang'aa and burning charcoal. They thought these activities might help them survive. Still, the health issues and the acceptability of the chang'aa option are unresolved, while the environmental sustainability of charcoal in an already degraded desert environment may not be feasible.

The community had suggested some options like the establishment of stable livestock markets, support education for their children, creation of awareness, especially on environmental conservation, restocking, development of infrastructure, continuous and adequate relief for both animals and people, awareness creation and capacity building as some of the ways of coping with climate vagaries and the provision for water for animals in the areas with pasture and lack water. Now, mobility is part of the respondents' lifestyle, and there were suggestions for mobility support. On a similar note, in its AR4 report, IPCC suggested livestock insurance schemes, credit schemes, and income diversification opportunities as possible viable adaptation options (IPCC 2007).

REFERENCES

Climate-Data.org. 2015. Climate: Maikona. http://www.en.climatedata.org/location/103875/. Accessed on 15th February 2015.

Davidson OK. 2003. The development and climate nexus: The case of sub-Saharan Africa. Climate Policy 3S1: S97-S113. DOI: 10.1016/j.clipol.2003.10.007.

DFID. 2009. Pastoralism and Climate Change, Pastoral Information Note 5. Natural Resources Institute, University of Greenwich, United Kingdom, .[Unpublished]

IFPRI. 2009. Climate Change Impact on Agriculture and Costs of Adaptation: Food Policy. International Food Policy Research Institute, Washington DC.

IPCC. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the IPCC. Cambridge University Press, Cambridge, UK.

IPCC. 2007. Africa, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

KARI. 2004. Transformation of Agricultural Research in Africa: Lessons from Kenya. Michigan State University Press, Michigan, USA.

Ketiem PK, Njunie MN, Wafula BW. 2009. Emerging Responses to Climate Change Adaptation Strategies in Arid and Semi-Arid Lands of Coastal Kenya. KARI, Kenya.

King JM, Parsons DJ, Turnpenny JR, Nyangaga J, Bakari P, Wathes CM. 2006. Modelling energy metabolism of Friesians in Kenya smallholdings shows how heat stress and energy deficit constrain milk yield and cow replacement rate. Anim Sci 82: 705-716. DOI: 10.1079/ASC200689.

Morton J. 2010. Pastoralism Information Note 5: Pastoralism and Climate Change. Natural Resources Institute, University of Greenwich, United Kingdom.

Mugenda OM, Mugenda AG. 2003. Research Methods-Quantitative and Qualitative Approaches. ACTS, Nairobi, Kenya.

O'Brien KL, Leichenko RM. 2000. Double exposure: Assessing the impacts of climate change within the context of economic globalization. Glob Environ Change 10: 221-232. DOI: 10.1016/S0959-3780(00)00021-2.

OECD 2001. OECD Annual Report 2001. OECD Secretary-General's Report to Ministers.

Srivastava AK, Rai MK. 2012. Review: Sugarcane production: Impact of climate change and its mitigation 13: 214-227. DOI: 10.13057/biodiv/d130408.

Thornton PK, van de Steer J, Notenbaert A, Herrero M. 2009. The impacts of climate change on livestock and livestock systems in developing countries; A review. J Agric Syst 101: 113-127. DOI: 10.1016/j.agsy.2009.05.002.

Watson RT, Zinyowera MC, Moss RH. 1998. The Regional Impacts of Climate Change: An Assessment of Vulnerability. Cambridge University Press, Cambridge, UK.

Waweru FM. 2010. Memoirs of Marsabit Town. http://www.fmwaweru.blogspot.co.ke/2010/02/memoirs-of-marsabit-town.html.

Witsenburg KM, Roba AW. 2004. Surviving Pastoral Decline: Pastoral Sedentarisation, Natural Resource Management and Livelihood Diversification in Marsabit District, Northern Kenya, [PhD Thesis] Amsterdam Institute for Social Science Research (AISSR)

World Wide Fund for Nature (WWFN). 2006. Climate Change Impact on East Africa: A Review of Scientific Literature. WWF, Switzerland.