Research Plan to Evaluate Steer Manure and Sawdust as Alternative Fuel for Cooking in East Africa

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Project Proposal: Scope of Work
November 9, 2017
Submitted to:
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1.0 Project Understanding

Roughly three billion people in developing countries lack access to energy [1]. Wood is the primary energy source used for cooking, heating, and disinfecting water. Consequently, increased fuel wood demand has lead to deforestation. Women in developing countries are responsible for cooking and collecting the fuel wood. These women have a high exposure rate to particulate matter (PM) from the smoke produced from cooking and boiling water, leading to serious health conditions such as respiratory disease [2]. The Alternative Cooking Fuel Research Project proposes to test different ratio mixtures of sawdust and steer manure, half using raw materials and half using pyrolyzed materials, to examine which mixture of fuel has the lowest PM emissions and is most efficient at boiling water. The testing will be done for each mixture with a cold start followed by four hot starts. The research team predicts that the pyrolytic fuel will have the lower PM concentration compared to the raw material fuel with the same mixture. Testing will be completed at the Northern Arizona University (NAU) Campus field station, Trotta's farm. In attempt to mimic the indoor conditions East African women are exposed to, a 10'x10' tent will be erected for testing in an area with the most protection from weather factors such as wind.

Figure 1: Map of Africa with Highlighted Region of Concern

1.1 Stakeholders

Women in rural developing communities in East Africa are the primary stakeholders. They are exposed to the health impacts associated with each task. Additional stakeholders include Dr. Dianne McDonnell, Dr. Fethiye Ozis, and The Northern Arizona University research team. Dr. Dianne McDonnell is the client. She provides insight on researching for sustainable alternative fuel sources. Dr. Fethiye Ozis is responsible for guiding the team's research. The capstone team will conduct the research and provide a recommendation of the best alternative fuel source based on the particulate matter emissions and boiling time for the cold start and hot starts.

1.2 Overview

Biomass cookstoves are widely used, impact human health, and contribute to deforestation.. Depending on the types of fuel and stove, they emit large amounts of pollutants including particulate matter (PM), carbon monoxide (CO), and organic compounds that could affect health. Household air pollution is the fourth worst health risk in developing countries after heart disease, stroke, and chronic pulmonary disease [3].

1.2.1 Traditional Cooking Method in Developing Countries

The three-stone fire is the traditional method for cooking in rural east Africa. This method requires three stones at the same height with the cooking pot placed in the center over a fire (Figure 2) [4].

Figure 2: Three-stone, open fire stove [5]

An improved cooking method also commonly used in East African is a metal stove or what is called "Jiko" in African language is more efficient and affordable than the ceramic stove. The improved, insulated Jiko stove can reduce fuel use by 30 to 50% [6].

1.2.2 Health Impacts

In developing countries, women play a crucial rule for being responsible for cooking and collecting fuel, spending more than five hours a day [7]. Women are not only affected from the smoke produced when cooking, but they also live in stress everyday in terms of distance travelled to collect fuel wood and the physical requirement to carry it. In many east African countries, women are travelling up to 3 km per day to government regulated forests for harvesting and collecting wood. Women are facing difficulties in searching, collecting and carrying a heavy amounts of wood daily. A study in Shimla and Sirmaur districts showed that the two biggest difficulties for women when collecting wood are time taken and physical stress from carrying heavy load (Figure 3) [1].

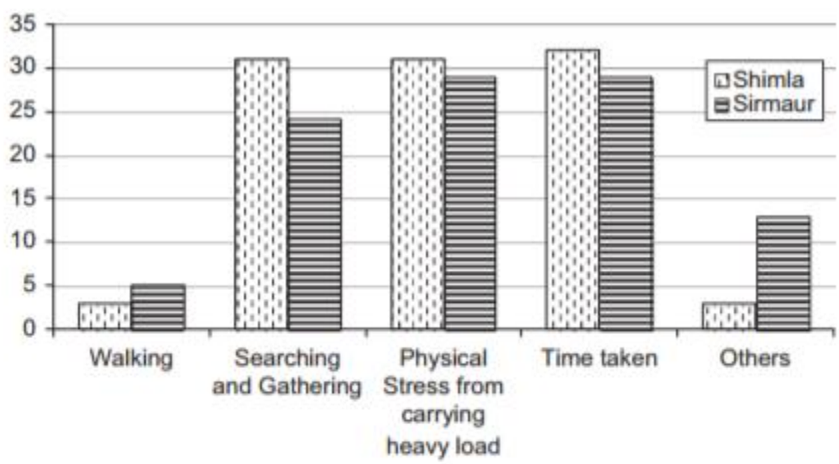

Figure 3: Difficulties for Women for Wood Collection [1]

Cooking, processors, and transporters are managed by women who, consequently, face a high health risk from particulate matter emissions. Excessive exposure may result in developing chronic obstructive pulmonary disease (COPD). Figure 4 below shows the type of activities women commonly take care of and their respective health impact.

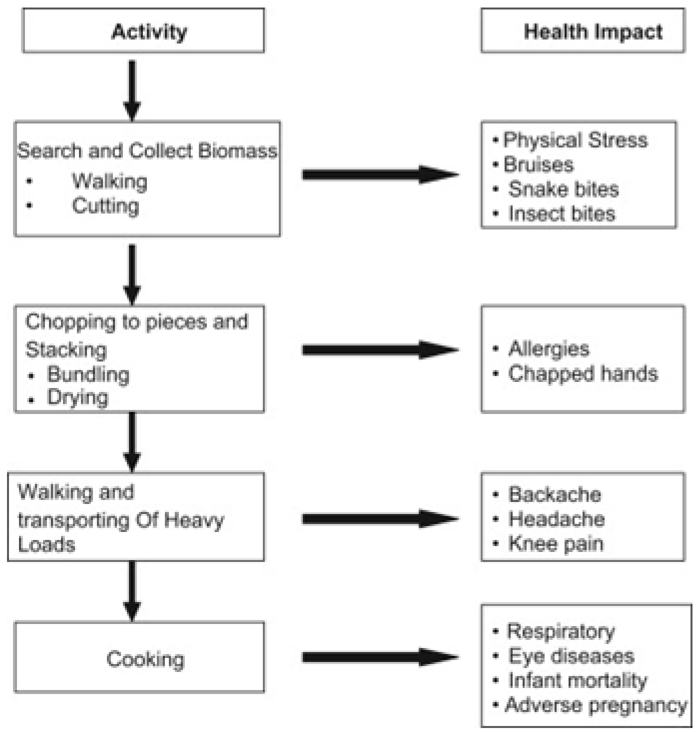

Figure 4: Bio-fuel Chain and Health Impacts

Most developing countries rely on burning solid fuels for cooking. In Bangladesh, exposure to smoke from cookstoves and open fires caused 122,000 deaths, with more than 93,00 children dying every year [8]. In Uganda, there are nearly 13,000 deaths yearly from exposure to smoke that releases PM, CO, and other contaminated pollutants [3].

1.2.3 Climate Change and Deforestation

Burning solid biomass fuels such as charcoal, wood, and agricultural waste produce a significant amount of gases and air pollutants that contribute to climate change and increasing global temperature [9]. Wood and charcoal used for cooking and heating in developing countries represent approximately 55% of global wood harvest and 9% of primary energy supply [10]. Wood burning and harvesting contribute to deforestation, which in turn decreases the amounts of oxygen produced by trees. For instance, when wood is harvested unsustainably and burned, CO2 gas emissions will not be absorbed as readily by trees, thus contributing to climate change.

1.3 Technical Considerations and Challenges

The team will conduct the testing outside the Trotta's Farm. The team will mimic indoor cooking environment to keep the results applicable to the target site, East Africa. To achieve this goal, the team will purchase a 10x10 tent, Additionally, to keep the testing conditions consistent, the team will conduct testing on days with warmer weather. This method will also mimic East African weather conditions because Flagstaff, Arizona typically has a cooler climate.

Test requires the burning of the fuel material, thus the team must carefully select a site to conduct the tests to prevent other substances in the surrounding area from being burned to prevent a fire accident. The team will avoid dry areas and heavily plant populated areas where a fire accident is more likely to occur.

Before conducting the tests, the team will be faced with the challenge of determining the standard briquettes. The pyrolization phase to find the best ratio of the briquettes may be time consuming but is necessary to design the shape of briquettes to fit the size of the jiko stove and ensure the airflow into the briquettes to maximize combustion.

2.0 Methodology

2.1 Obtain Materials

Two types of fuels will be obtained, steer manure and sawdust. These fuels are different in which steer manure is an animal waste which is moist and sawdust is dry. Sawdust will be obtained from a local sawmill based on the type of wood they are able to provide and cost. The local sawmills which will be considered are A P Sawmill and Lumber Prod, Spellman Hardwoods, Probuild, E. T. Moore Manufacturing Inc, and McCoy Millwork. The steer manure that will be used is Earthgro Steer Manure Blend which will be obtained from the local Home Depot store.

The rest of materials will be obtained from NAU, including:

- One insulated Jiko stove provided by Dr. McDonnell from East Africa.
- Thermometer
- Omega Handheld Particulate Pollution Meter
- Apple iPhone application stopwatch
- One liter of water at room temperature

2.2 Prepare Samples

Three different ratios of a mixture of sawdust and steer manure will be designed as briquettes and the same three ratios will be designed as pyrolyzed briquettes. A prototyping phase will be performed to help determine the final shape and design ratios of briquettes for testing. During this phase, only the time taken to boil water will be measured to ensure actual testing does not exceed the scheduled time. A total of six different variations of fuel will be analyzed during the research which included the following:

1. 75% Sawdust and 25% Steer Manure Briquettes
2. 50% Sawdust and 50% Steer Manure Briquettes
3. 25% Sawdust and 75% Steer Manure Briquettes

4. 75% Sawdust and 25% Steer Manure Pyrolyzed Briquettes
5. 50% Sawdust and 50% Steer Manure Pyrolyzed Briquettes
6. 25% Sawdust and 75% Steer Manure Pyrolyzed Briquettes

The percentages of materials shown above are by weight. The actual weight for testing of each briquette will be determined during the prototyping phase.

2.2.1 Step 1 : Dry Materials

The team will determine the amount of each material required for both fuels to make six different ratios. Steer manure is moist, therefore it is necessary to dry before making the mixtures. The purpose of this procedure is to keep the moisture content consistent for all mixtures by ensuring there is not weight added by water. Steer manure will be dried within 24 hours in an oven in environmental engineering lab at NAU.

2.2.2 Step 2 : Mix Fuels

A mixture of steer manure and sawdust will be created based on the ratios determined by weight during the prototyping phase. Before mixing, the team will record the weight for each sample. Next, the sawdust and steer manure will be mixed by adding a cup of water for all six mixtures. The team will record the weight for the moist mixtures and put them in the oven to dry for at least 24 hours. Once the mixtures are dry, the weight will be recorded to calculate the moisture content. It is important that all the briquettes are strongly compressed and have similar shape and size to keep the testing results consistent.

2.2.3 Step 3: Pyrolyzing 50% of the Briquettes

Pyrolization for solid biomass must be completed at relatively low temperatures in order to retain biochar compared to high temperatures which will produce more gases. Due to this, the briquettes will be pyrolyzed using an oven, in a controlled environment, set to 1000 degrees Fahrenheit. Modern day pyrolization is done in the absence of air; however, due to technological restrictions this is unachievable during the Research Team's sample preparations. The low temperature pyrolysis must be done over the course of several hours, thus the briquettes will be placed in the oven for 24 hours [11].

2.3 Run Testing

Each mixture ratio will be tested five times, starting with a cold start followed by four hot starts.

Test 1: Cold Start

Fill the pot with one liter of room temperature water and place the thermometer in the center to determine the water temperature and record it. Put the mixture of fuel in the stove and start the fire. Once the fire is caught, start the timer and record the starting time while having the PM counter three feet above the stove and measuring the PM concentration until the water boils. When the water reaches the boiling temperature, indicated by the thermometer, record the time and the emission measurement and discard the hot water.

Test 2: Hot Start

Hot start testing will be done four times for each ratio, beginning immediately after completion of the cold start testing. First, refill the hot pot with a one liter of room temperature and record its temperature using thermometer. Next, ignite the fire and start the timer while maintaining the PM counter at the same height as the previous tests. Once the water reaches the boiling temperature, record the time, end emission measurements, and discard the hot water.

2.4 Data Analysis

The data will be analyzed in Excel as linear regression chart using charts for each ratio of fuel that show the time it took to boil water and the variation of PM concentrations for both cold and hot start testing. The charts and graphs will then be used to compare the results for all the ratios and determine which mixture produces the least amount of PM and boils the water in the shortest time.

2.5 Deliverables

2.5.1 50% Report

In the first half of the semester, the amount of fuel briquettes and their sizes will be determined during the prototyping phase. Prototyping will consist of experimenting with the briquettes ability to raise water to boiling temperature only, therefore no particulate matter concentrations will be recorded. Once the correct briquette shape and size are established, briquette samples used for testing will be formed and dried. The six sample types will each be tested five times in the second half of the research time frame.

2.5.2 Final Report

The final report will display the full results and analysis from the testing completed during the course of the semester. The results will show the testing done to determine the proper briquette sizes to efficiently boil water, the testing done with the different samples to determine boiling effectiveness, and the testing done with the different samples to determine the particulate matter emissions. Graphs comparing the results will be generated to analyze the data with a visual representation. Lastly, the best alternative fuel combination and briquette sizes using saw dust and steer manure will be concluded based on boiling time and the EPA air quality standards.

2.5.3 Website

The results from the research as well as the conclusions drawn will be placed on the "Project Information" page that was previously left blank. While the information is being added, the focus will be ensuring the content being added to the page is easy to read, detailed, and concise. This will include making the webpage as effective as possible by keeping it user friendly with minimal links that are fully operational. The final design of the website will have a professional display on the "Home Page" with links to the "Documents" and "Project Information".

2.5.4 Final Presentation

The final presentation for will follow the format of the Research Report deliverable and include the same information. A Powerpoint presentation will be created using Microsoft Powerpoint to visually display important information and pictures from the project. The presentation duration will be roughly 15 minutes, but no more than 20 minutes. This includes the question and answer portion of the final presentation deliverable, therefore the presentation must be completed in a timely manner for questions afterwards.

2.6 Research Management

Within the completion of the research and the course deliverables, there are other time sinks which must be planned for. Client/Grading instructor meetings will occur biweekly which account for an hour each meeting. Biweekly meetings with the Technical Advisor will also occur and account for an hour each meeting. Team meetings occur for roughly 30 minutes weekly, adding another biweekly hour time sink. Meeting times will account for one to two hours of time dedicated to the project per week for the first half of the semester during prototyping and pre-testing. In the second half, meetings will be held on a “as needed” basis for guidance regarding testing and data analysis.

Reserving the lab testing area for use as well as setup for testing will also take a short amount of time, but must be scheduled for to ensure the success of the project. During testing, at least two members will have to be recording data, which will then need to be translated onto a computer to be made available to all members. This is one of three primary weekly tasks, the second being updating the team’s schedule as unplanned for events arise. The schedule should be updated after each testing session as well as in the event of a schedule change for outside causes such as weather. Remaining updated on the project binder always will require weekly time such as adding meeting agendas, meeting minutes, data results, etc.

2.7 Project Limitations

The team attempted to receive approval to burn the fuel inside Trotta’s farm from the NAU engineering department Lab Manager, Adam Bringhurst. However, due to safety concerns, permission was not granted and testing must be performed outside. The equipment the team requires is limited because the only resource of those devices is NAU’s Laboratory in the engineering department. Due to budgeting and availability, access to other devices not obtained by NAU’s engineering department is not plausible. Borrowed equipment should be used carefully, following the instruction of Mr. Bringhurst to ensure the devices are not damaged or broken.

3.0 Schedule

The project starts on January 15th in 2018. The first task is site preparation, which will last roughly 5 days to January 19th in 2018. The team will acquire materials from January 24th to January 31st in 2018. Optimizing procedure will be conducted for three days from February 3rd to February 6th in 2018, which will include determining proper briquette size. Sample preparation will begin with making briquettes from February 10th to February 14th in 2018. The testing is divided into six groups, the team will spend one day for every group of tests. The testing of the different combinations of briquettes will be from February 17th to February 27th. The team will spend three weeks analyzing data and creating graphs for comparison from March 1st to March 21st in 2018. Finally, the final report will be written following testing and analysis, concluding on April 30th, 2018. The gantt chart on the following page displays the schedule of the tasks to be completed and the critical path to complete the research and analysis in a timely manner.

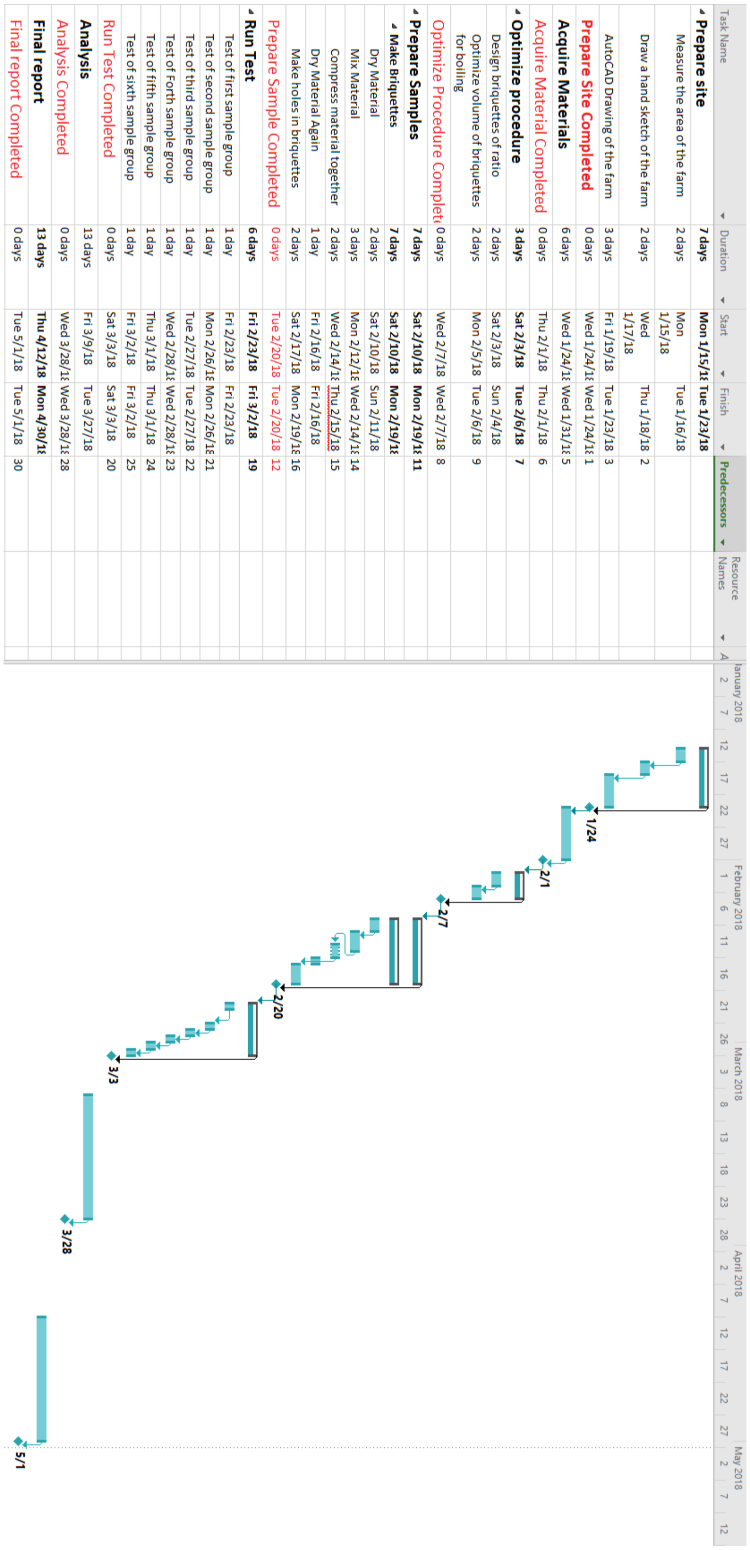

Figure 5. Gantt Chart

3.1 Critical Path

The site preparation must be done at the beginning of the 2018 spring semester. This procedure will last seven days from 15th January in 2018. The materials need to be obtained immediately after site preparation, then the pre-testing will be conducted to determine the size, volume, and ratio of briquettes. These two procedures will be completed in nine days beginning January 24th, 2018. Sequentially, the materials will be prepared as briquettes for testing over the following seven days.. The materials can not be laid aside for too long because impurities in the surrounding environment may get into the materials and affect their ability to burn. After the sample preparation, the team will begin testing and data collection. The duration of testing will be six days which will conclude the field testing portion of the project. With testing completed, there are 13 days dedicated to analyzing the data in Microsoft Excel. The final report will start once the data analysis is completed, and the team will spend 13 days to finish the report. The expected duration of the project is roughly four and a half months, beginning January 15th, 2018 and concluding May 1st, 2018.

4.0 Project Staffing

4.1 Staff Members

The staff (research team) for this project are the: senior engineer, junior engineer, lab manager, and project manager. Each staff member will have responsibilities required of them to complete the project within the scheduled time frame.

4.1.1 Senior Engineer

The senior engineer needs to be present at all of the testing sessions to ensure procedures and criteria are being met. They will also review the test results to determine the accuracy of the results as well as the outliers within the data set. It is the responsibility of the senior engineer to review the data analysis and validify them. The senior engineer should have the skills of working in the field and effectively communicating with the team.

4.1.2 Junior Engineer

The junior engineer will perform the testing and form the samples. This includes drying and weighing the materials, combining the materials to form briquettes, setting up the testing space properly, ensuring all equipment is on hand, and recording the temperature of the water while boiling. The junior engineer is also responsible for delivering the test results to the project manager and cleaning the workspace/equipment after testing. The skills required are working hard, communicating with the staff, and managing time.

4.1.3 Lab Manager

The lab manager must be present during all activities performed in the lab such as pretesting, briquette formation, and all testing. During this time, it will be the lab managers responsibility to ensure all equipment and lab space is being used properly as well as preserving the safety and health of all team members depending on conditions and hazards. The skills required are lab training, communicating, and providing guidelines for junior engineer when working with lab equipment.

4.1.4 Project Manager

The project manager will be responsible to provide the overall direction and requirements for the project. The project manager must be present for all pre-testing operations including briquette formation and burning test trials. Project manager shall be present for actual testing briquette sample formation for both the raw material and charcoaled. The project manager is also responsible for collecting the test results and analyzing them through the creation of graphs in

Microsoft Excel. The skills required are, professionalism, working as a leader and managing time.

5.0 Cost of Engineering Service

5.1 Cost of Staff

The hourly rate of a senior engineer is $150/hr, which will be the base pay for the billable hours of the senior engineer for the work previously discussed [12]. Additionally the hourly rate for the lab manager is $45/hr [13] and the hourly rate for the project manager is $65/hr [14]. The last staff member of the research team is the junior engineer, who will have an hourly rate of $25/hr [15].

5.1.1 Cost Of Staff Analysis

The cost of service from each staff member is based on the total hours spent working on the project. The time allocations in Table 2 are split into three phases: acquiring materials and prototyping tests, final sample preparation and testing, and data analysis. The cost of overhead, benefits, vacation, etc. is roughly three times the base salary of each employee. The total cost column of Table 2 displays the cost of each employee’s service with the three multiplier.

Table 1: Cost of Staff Members and Services

Team Member	Hourly Rate	Hours for Prototyping Phase	Hours for Sample Preparation and Testing	Hours for Data Analysis	Total Hours	Cost	Total Cost
Senior Engineer	$150/hr	10	15	10	35	$5,250	$15,750
Lab Manager	$45/hr	10	20	10	40	$1,800	$5,400
Project Manager	$65/hr	15	15	10	40	$2,600	$7,800
Junior Engineer	$25/hr	20	25	30	75	$1,875	$5,625
Final Cost							$34,575

5.2 Cost of Materials and Equipment

The alternative waste being used will be purchased from Home Depot while the sawdust will be purchased from a local sawmill. A 10x10 foot tent will also be purchased from a Walmart store. The insulated jiko stove, thermometer, particulate meter, and land space being used will be provided by the NAU engineering department and is therefore not included in the cost analysis.

5.2.2 Cost Analysis of Materials and Equipment

Table 3 displays the cost associated with the materials and equipment needed for research and data collection for a four month period.

Table 2: Cost of Materials and Equipment

	Quantity	Unit	Unit Cost	Total
Sawdust	10	Pounds (lbs)	$2/lbs	$20
Steer Manure	2	Bag (CF)	$1.47/bag	$2.94
10x10 Tent	1	N/A	$109.99	$109.99
			Total Cost	$132.93

The total cost of the research product will will be $34,707.93 which includes the cost of the staff members, staff services, equipment, and materials.

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