AGRIVOLTAICS IN SOUTHERN AFAR, ETHIOPIA

MIKA LEW, MUSKAN JAIN, PARSHWA PATEL, RISHIT JAIN, YASH KHANDELWAL (YASHK4@ILLINOIS.EDU)

The Key Problem: Food Insecurity, Lack of Electricity, and Civil War in Ethiopia

According to the National Electrification Program of Ethiopia, only 44% of the Ethiopian population has access to electricity. One region that we have decided to focus on is Afar. This region especially has severe energy shortage issues due to improper infrastructure development and high capital cost for hydro-powered electricity (American Journal of Modern Energy, 2021). In addition, an ongoing civil war has further introduced more obstacles to Afar's electricity access as more than half of the transmission lines were destroyed by the terrorist organization, TPLF, at the start of 2022. However, with the current peace talks, **the application of an agrivoltaics + solar-powered hydro pump** on farmlands can boost economic development through energy and food security in the Afar region.

SDG GOALS ACHIEVED

Goal 7 ▶ Affordable and Clean Energy

Agrivoltaics will generate clean energy through solar power on the farmlands. This will generate a passive income for farmers by making the energy affordable.

Goal 9 ▶ Industry, Innovation, and Infrastructure

The use of agrivoltaics will allow the creation of a micro-grid system for farmlands and boost local industry through increased production and demand for solar panels that would create a sustainable and reliable electricity infrastructure in rural areas.

Goal 11 ▶ Sustainable Cities and Communities

Solar energy will promote sustainability and will lead to more energy-reliant communities.

Goal 13 ▶ Climate Action

Transitioning from fossil fuels to solar energy while increasing crop growth in communities can help fight climate change.

WHY SOUTHERN AFAR?

One of the main factors in considering Afar was that the photovoltaic generation is sufficient as shown in figure 1. Additionally, the region's rainfall is ideal; it is neither excessively heavy or low and is enough for our targeted plant, cabbage, which needs 600 - 900 mm of rainfall. Southern Afar is situated between valleys and has the Awash River basin running through it. Also, solar panels are rated to perform at peak efficiency between 59°F and 95°F. Thus, another pro for choosing Southern Afar was that the average temperature is around 85°F. Further, Southern Afar has flat farmlands allowing for consistent solar systems and lesser complications.

WHY CABBAGE?

As for crop, the main reason for choosing cabbage is that it is advantageous from an economic standpoint. Cabbage, in the past, has been successfully used for agrivoltaics across various countries like Kenya that has similar physical and geographical characteristics. Cabbage requires around 6-8 hours of sunlight in a day and Southern Afar's weather conditions allow for proper sunlight. Further, cabbage can add on to the food security plans for the country. Since, cabbage is grown in the surrounding regions of Afar, it will be easier for the farmers to adapt. Last but not least, another reason for selecting cabbage is the size, which allows us to place solar panels at a lower height leading to lower installation costs.

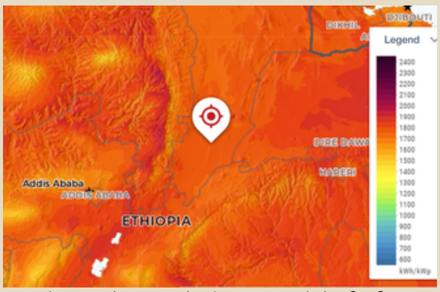

Fig 1.: Photovoltaic Potential of Afar

Fig 2.: Terrain map of Afar

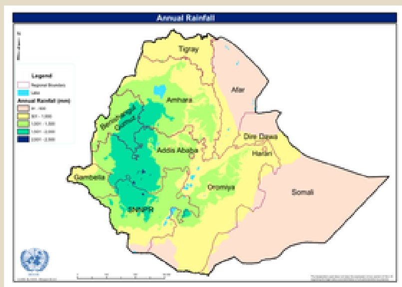

Fig 3.: Precipitation map of Ethiopia

TECHNICAL FACTORS

- ▶ Monocrystalline Panels are easily available and commonly used in the Afar region. They will also have the highest efficiency-to-cost ratio, being up to 22% efficient.
- ▶ Placing the panels in a Zig-Zag pattern will be the most beneficial to the crops while covering up to 44.6% of the farmland in solar panels. Estimated annual production is 461.12 kWh/m2 assuming the panel size to be 65 x 39 inches.
- ▶ During dry spells, cabbage needs 1-1.5 inches of water per week. Assuming that this water will be transported to the farmland through the Awash River basin, the drip irrigation system will use 0.295 kWh/m3 of electricity directly out of the solar system.

- Panels placed at an angle of 14° year-round, or 0° during the summer and 29° during winters will give maximum efficiency. Panels are the most efficient when they are tilted at the same angle as the latitude of the place.
- Solar Panels have proved to decrease the amount of irrigation needed by as much as 47% while increasing the yield of cabbage by 24%
- Panels placed at a height of 4.85 metres will provide the best shade to the cabbage crops.
- Plants, being evaporative coolers, will increase the efficiency of solar panels in hot weather, increasing the daily output by about 13%. Monocrystalline panels, above 95°F, start losing their efficiency. The plants will help the panels maintain their efficiency.

ECONOMICAL FACTORS

Factors	Results	Application
Batteries	Lead-Acid Batteries	Due to their low cost and good dependability, lead-acid batteries are frequently utilized in inert applications. Because they are widely accessible throughout Africa and are inexpensive to use, lead-acid batteries are perfect for our agrivoltaic system.
Solar System with HydroPump	• 300W Solar Panels • Drip irrigation system with the tubing above ground	• Installing (the full solar system) a solar panel over a hectare would cost between \$4.2M and \$9M, and maintaining all the solar panels would cost \$0.3M. (approximately 2000 panels over a hectare). Additionally, the total price per hectare for constructing and maintaining the hydro system is \$5300. • The overall cost over a ten-year period would be \$12–\$16 million.
Funding	Approx \$600 Million	The project's funding will come from a variety of funds allocated for projects like it, including a \$1 million US fund from the IFC World Bank, \$15 million from Anannese Programs, \$5.5 million from the Africa Development Fund, and 500 million US dollars from the New World Bank, which together with other NGO and government funds amounts to approximately \$600 million.
Cost of growing Cabbage	approximately 656.36 USD	Cabbage may be grown manually on an acre for about 656.36 USD overall, which covers labor costs per bag, fertilizers, crop protection, and crop maintenance.
Profitability/ Revenue	\$6.4 Million USD (in profits) assuming a farmer has over 10 acres of land	Farmers' Current Wages are Approximately \$900 USD when done manually, but it is predicted to increase to an average of \$5000 USD per acre per year once the system is in place. Given that a farmer has more than 10 acres of land, their annual income will exceed US\$6.4 million (in profits)

SOCIAL FACTORS

No matter how advanced technology is, it is crucial that the targeted community is receptive to it. In order to make our system more adaptable, we are going to reference a farmer adaptability case study on water harvesting technology conducted along with a socioeconomic development study done in Afar, Ethiopia specifically. In the farmer adaptability case study, the four main factors contributed to adaptability:

- **Biophysical characteristics:** flat land and installment of technology that was cheap and easily removed were more favorable among farmers.
  - **Application**: Afar is relatively flat (91%) compared to the the whole country (56%). In addition, cabbage grows relatively low compared to other plants such as coffee. Thus, the pier needed for structural support will be minimized meaning the possibility for removal is eased.
- **Capital ownership/Off-farm activity/Social Capital:** wealthier farmers that had alternative sources of income were more likely to adopt because they can take upon more risk. In addition, households that had a larger number of relatives and wider networks were likely to adopt technology due to the same reason.
  - **Application**: Approach more affluent owners rather than small-scale farms initially. This allows owners to divert their attention to management rather than physical labor.
- **Household characteristics:** Educated male-led farms were more likely to adopt technology because women generally face gender-specific constraints such as less education, inadequate access to land, and production assets and livestock ownership, that make them less likely to adopt.
  - **Application**: Aim for owners that have an educational background. In Afar, 58% of the population is educated given that the measure is based on whether they had six years of schooling.

- **Access to Markets:** Farmers who had more access to information and support services were more likely to adapt.
  - **Application:** Start implementing our solution in larger communities to slowly bring awareness and increase the supply chain of our components. Then, we would be able to extend our solution to more rural areas and also show the agrivoltaic+hydro pump system we have placed.

GOVERNMENT POLICIES

Growth and Transformation Plan: Support towards large-scale commercial farming, green revolution and reforestation, water management, upgrading transmission lines

Productive Safety Net Program (PSNP): Elaborated plans for resilience in case of any crisis like drought or economic depression

Plan for Accelerated and Sustained Development to End Poverty (PASDEP): Massive investment to increase agricultural productivity and production

Climate Resilient Green Economy Program: Objectives similar to Growth and Transformation Plan

Agricultural Transformation Agency (ATA): Focuses on improving the organizational structure of the complete bureaucratic processes

Reduced subsidies for fossil fuels and price controls to make crop production more economical for the complete chain

Special government units to expedite the leasing processes to promote commercial farming: This allows the federal government and took charge away from local governments to remove conflicts

CONCLUSION

- **Introduce a self-sufficient electricity generating system:** Buying electricity from the national grid is quite expensive. Reliance on the national grid can be reduced with the introduction of agrivoltaic system.
- **Saves crops from UV damage and droughts:** Afar region faces unprecedented droughts caused by global warming which is affecting food and water security. Putting shade over those crops shields them and protects them from UV damage and drought. This creates a more favorable growing environment and curbs some of those extreme conditions
- **Increase and regain cabbage production:** Cultivation of cabbage is slowly dying in the Afar region because of extreme climate conditions. Our solution has shown promising results in the past in Kenya with the yields increasing by around 16% (DW, 2022). Hence, our proposal can rejuvenate the farmers and give them hope to not give up on cultivating cabbage.
- **Expansion of the system:** Increased crop production and electricity generation will eventually inspire neighboring regions to employ this system.
- **Economic gain:** The revenue is expected to increase to up to $5000 USD per acre and assuming that the farmer own more than 10 acres of land the total profit generated will be more than $6.4 Million.

ACKNOWLEDGEMENT

We would like to sincerely thank **Basia Latawiec** (latawic2@illinois.edu), Project Coordinator for USDA SCAPES (Agrivoltaics), and **Meredith Moore** (mkm0078@illinois.edu), Sustainability Programs Manager at UIUC for their valuable guidance and encouragement throughout the project.

1. Evans Security Ethiopia - new york university. (n.d.). Retrieved November 19, 2022, from https://cic.nyu.edu/sites/default/files/evans_security_ethiopia_2012.pdf
2. Solar energy potential and future prospects in Afar Region, Ethiopia. (n.d.). Retrieved November 19, 2022, from https://article.sciencepublishinggroup.com/pdf/10.11648.j.ajme.20210702.12.pdf
3. Matalucci, S. (2022, May 30). The AGRIVOLTAIC projects stirring interest in Africa – DW – 05/30/2022. dw.com. Retrieved November 19, 2022, from https://www.dw.com/en/climate-change-puts-agrivoltaic-projects-in-northern-africa-in-the-spotlight/a-61972022
4. authors, A., Benti, N. E., & Additional informationFundingThe authors received no direct funding for this research.Notes on contributorsNatei Ermias BentiNatei Ermias Benti holds a PhD in Environmental Science from Addis Ababa University (stream: Atmosphere. (2018, October 1). Estimation of global solar radiation using sunshine-based models in Ethiopia. Taylor & Francis. Retrieved November 19, 2022, from https://www.tandfonline.com/doi/full/10.1080/23311916.2022.2114200
5. How efficient solar panels are in 2022? GreenMatch. (n.d.). Retrieved November 19, 2022, from https://www.greenmatch.co.uk/blog/2014/11/how-efficient-are-solar-panels#:~:text=Solar%20panels%20are%20usually%20able,%2C%20weather%20conditions%2C%20and%20similar.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN